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Transportation Energy Management

Energy Efficiency in Transit Buildings

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Transportation Energy Management:

Energy Efficiency in Transit Buildings

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Prepared by
Municipality of Metropolitan Seattle

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January 1984

EXECUTIVE SUMMARY

This report is written for planners and facility managers who want to minimize transit building utility costs. The report's subject is energy efficiency, the effectiveness with which energy is used in a building. The report suggests a number of measures which can reduce a transit agency's energy consumption by 10% at little or no cost, and by an additional 20% by installing equipment with a payback of less than 5 years. The report contains ten chapters, each of which is summarized below.

(1) Energy Management Tools

"How much energy do the garages use?" To answer that question many transit agencies have developed energy bookkeeping systems. A good energy bookkeeping system will record month-to-month variations in energy consumption as well as energy costs after factoring out the effects of weather. Energy bookkeeping saves money by helping transit managers spot billing errors and equipment problems.

A quick way to evaluate a potential energy project is to calculate its simple payback--the length of time it takes for the project's energy savings to equal the project's costs. However simple payback has a disadvantage: it ignores both the time value of money, and the effect of rising energy prices on a project's feasibility. Two other forms of evaluation, present worth analysis and life cycle analysis, are more reliable than simple payback, but more difficult to calculate. They are worth the trouble only if a project costs more than $20,000 or has a useful life of at least 15 years.

(2) The Heating, Ventilation and Air Conditioning (HVAC) System

HVAC systems account for 75% of all energy use in transit buildings. The least-cost way to save HVAC energy is to set transit building temperatures below 68° in the winter and above 72° in the summer. Bus storage areas should be kept at 50° in the winter. Setback thermostats, which re-adjust temperatures when a transit building is unoccupied, can reduce heating bills by 10-20% with a payback of less than one year. HVAC energy savings of up to 50% can be achieved by installing equipment to recover heat from exhaust air. In transit buildings, heat recovery equipment has an average payback of 6 years.

(3) The Building Envelope

The greatest source of heat loss in most transit buildings is the leakage of outside air into the maintenance shops through open overhead doors. Air curtains are the best device for reducing heat loss through heavily travelled bus entrances and exits because they allow a bus unobstructed passage into a building. Magnetic loop automatic doors are the most reliable and inexpensive way to cutting heat loss through moderately travelled maintenance bay doors.

(4) Lighting

Lighting is the second largest energy user in most transit facilities. A transit facility can reduce its lighting bill at little cost by removing excess lamps if lighting levels exceed two watts per square foot, and by substituting low wattage energy saving lamps for existing lamps which have burned out. Projects to install local switches or replace incandescent and mercury vapor lamps will have a payback of less than

three years in transit buildings where lights run continuously, or electric rates are above 7¢ per kwh.

(5) Hot Water

Domestic hot water systems are very small energy users, but hot water losses can be limited at little or no cost by turning hot water temperatures down to 105° and by insulating hot water storage tanks.

(6) Innovative Energy Projects

An energy management system (EMS) is a computer system which controls and monitors energy use. EMS's can cut energy bills by starting and stopping equipment, by turning off low priority equipment when a building's electric demand is at its peak, and by turning off HVAC equipment to allow a building to "coast" for short periods during the day. EMS's cost between $20,000 and $300,000 but may still be feasible in transit buildings if utility bills equal $100,000 a year, electric demand charges are high, or a building is occupied continuously.

Burning Waste Oil: Seven transit agencies use waste oil as a heating fuel. Waste oil heaters are good energy investments. They can cut heating bills by 75% with a payback of less than a year. There are three rules for transit agencies which want to avoid equipment problems: (1) don't burn waste oil in a boiler without modifying the boiler to handle it, (2) keep the quality of the waste oil as high as possible, and (3) maintain the equipment.

(7) Solar Energy

This study identified seven transit agencies with active solar heating, eight with passive solar heating, and six with solar domestic water heating. Active solar transit projects are poor investments: they have paybacks greater than 20 years and are usually not as reliable as conventional HVAC systems. Some passive solar projects, such as trombe walls, appear to be good investments with paybacks as low as seven years; other passive projects such as skylights and glass blockwalls, are poor energy investments, but can sometimes be justified for aesthetic reasons. Solar hot water systems have a payback of less than 10 years only if transit agencies heat water with expensive fuel such as electricity and are located in an area which gets lots of winter sunshine.

(8) New Buildings

This study identified 18 transit buildings which are less than 2 years old. Most have the following energy-saving features: internal circulation, automatic doors, heat recovery, skylights, efficient lights, south exposure siting, and solar heating. Lighting projects are cost-effective for all new transit facilities, regardless of climate. Internal circulation, automatic doors, and heat recovery are cost-effective in cool climates. Solar heating is rarely cost-effective.

(9) Getting Organized To Save Energy

Transit agencies have tried two different approaches to energy management: some agencies use energy management teams, others delegate the responsibility to a single individual. Although the success of an energy management program doesn't appear to depend on whether a program is assigned to an individual or a team, two things are evident about those agencies with a strong energy management record: one person, one office, or one committee is clearly held responsible for energy management;

and someone closely monitors energy use and investigates sudden changes in consumption.

(10) Conclusion

This report identifies three types of projects which help transit managers reduce energy bills: low cost projects, moderate cost projects and high cost projects.

Low cost projects have capital expenses of less than $1,000 and can be expected to reduce energy bills by 10-15% with a payback of less than one year. Examples include setback thermostats, delamping, and replacing lights which burn out with smaller wattage lights. Low cost projects are appropriate for implementation in all transit facilities.

Moderate cost projects involve capital expenditures of $1,000-20,000, and will have paybacks of less than 5 years. They include such measures as installing local light switches, converting to high efficiency lighting, and installing waste oil heaters. The moderate cost projects should be included in any facility expansion or rehabilitation.

High cost projects have capital expenses of $20,000 or more. These projects require careful analysis, but they can reduce energy bills dramatically. Examples of high cost projects include lighting dimmer systems, heat recovery equipment, internal circulation and automatic doors, radiant heating, and energy management computers. These projects are excellent candidates for inclusion in UMTA facility construction grants.

ENERGY EFFICIENCY IN TRANSIT BUILDINGS

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Chapter 1

INTRODUCTION

Objectives and Organization

This report is written for planners and facility managers who want to minimize transit building utility costs. The report's subject is energy efficiency--the effectiveness with which energy is used in a building. The objectives of this report are to:

(1) **Suggest ways to improve the energy efficiency of transit buildings.**

(2) **Provide examples of transit agencies which have saved money through energy efficiency improvements.**

The report is divided into 10 chapters. Chapter 2 is most useful for transit managers who are interested in energy management, but aren't sure how to proceed. It discusses how to monitor energy consumption, and how to evaluate energy efficiency projects. The next 6 chapters are most useful to transit managers who are looking for specific energy efficiency ideas. Chapters 3 through 6 discuss major sources of energy waste associated with a transit facility's heating, ventilation, and air conditioning system (Chapter 3), building envelope (Chapter 4), lights and equipment (Chapter 5), and domestic hot water system (Chapter 6). Chapter 7 analyzes three additional energy efficiency measures--energy management computers, waste oil heaters, and co-generation equipment--which have been successfully implemented at some transit properties. Chapter 8 explores the use of solar energy in transit facilities. Chapter 9 discusses the energy efficiency features of most new transit buildings, and should be useful to transit managers with new buildings in the planning or design stage. Chapter 10 examines how transit agencies organize for energy management.

Methodology

In April and May of 1982, Seattle Metro's energy office conducted an energy management survey of 108 transit agencies in the U.S. and Canada. The results of that survey are contained in **Transportation Energy Management: Current Operator Activities**, published in September 1982 by the Urban Mass Transportation Administration. Work on this report, which is a follow-up to that survey, proceeded in three stages: First, the staff of Metro's energy office assembled a list of transit agencies which were good candidates for follow-up interviews based on responses to the 1982 survey. This list was supplemented with suggestions provided by UMTA engineers in each of the 10 federal regions. Second, between August and November, 1983, 71 phone interviews were conducted with individuals representing 55 different transit agencies in the U.S. and Canada. Third, site visits were made to Salt Lake City, Utah; Denver, Colorado; Syracuse, New York; Portland, Oregon; and Everett, Washington. During these site visits, walk-through examinations of transit buildings containing energy efficiency equipment were conducted, and additional information was gathered from building floor plans, feasibility studies, and project specification sheets.

Background

Why is energy efficiency important?

Energy efficiency is important because energy prices are increasing rapidly, and constitute a significant portion of the operating budget. Prior to 1973, and the first of 2 energy crises in that decade, energy prices remained stable at a relatively low level. However, the environment has changed significantly since 1973. Table I summarizes the effect of energy price increases over the past decade. It shows that in the last 10 years electricity prices have increased by 213%, natural gas prices have increased by 471% and oil prices have increased by 436%. That amounts to annual increases of 21% for electricity, 47% for natural gas and 43% for heating oil.

Table I

Fuel Price Increases: 1973 - 83

Fuel	1973	1983	Percent Change
Electricity (per kwh)	$0.0196	$0.0612	+213%
Natural Gas (per therm)	$0.108	$0.617	+471%
No. 2 Heating Oil (per gallon)	$0.22	$1.18	+436%

Source: Monthly Energy Review Energy Information Administration, U.S. Department of Energy; July 1983.

After inflation has been accounted for, energy prices have been increasing at a rate of between 10 to 15 percent a year. If transit managers do not pay attention to energy costs, they will be forced to devote more of their budgets to utility bills and less to items such as new equipment or driver training. It doesn't have to be that way, however. In most buildings, energy consumption can be reduced 10-15% by changing building operating patterns, or by installing equipment which will pay for itself within a few months. Moreover, an additional 15-20% savings can be realized by installing equipment with a payback of less than five years.[1]

Energy Use in Transit Facilities

Transit buildings are moderately-heavy energy users. Seattle Metro's 1981 survey of 108 North American transit systems showed that they consumed an annual average of 85,790 British Thermal Units (BTU's) of energy per square foot of building. Transit facilities in Canada and the northern U.S. used between 150,000 and 200,000 BTU's per square foot. Table II compares these figures with data for other building types.

---

[1] Milton Williams, "Organizing an Energy Management Program," in Energy Management Workbook, edited by Wayne C. Turner, (New York: John Wiley & Sons, 1982), p. 7-8.

It shows that transit buildings tend to use more energy per square foot than schools, apartments and stores, but less energy per square foot than hospitals and high-rise office buildings.

Table II

1979 Energy Consumption in U.S. Buildings

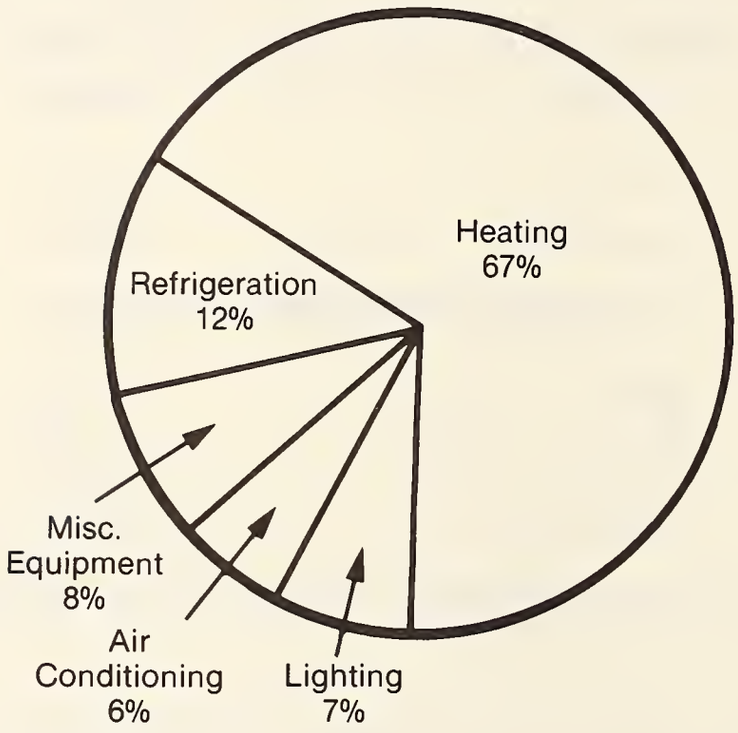
Building Type	BTU's/Sq.Ft.
Hospitals	179,000
Offices	103,000
Warehouses	94,000
Transit Maintenance Facilities	**85,790**
Retail	78,000
Schools	66,000
Apartments	60,000

Sources: 1981 Metro Energy Management Survey; 1979 U.S. DOE Non-Residential Energy Consumption Survey.

Transit maintenance facilities can be expected to have an energy profile which is similar to that of warehouses. Transit buildings and warehouses use roughly the same amount of energy per square foot; and they have large exterior doors which are frequently opened. Figure 1 is a profile of energy use in warehouses in the United States. Figure 2 is an energy profile for a Seattle Metro bus base.

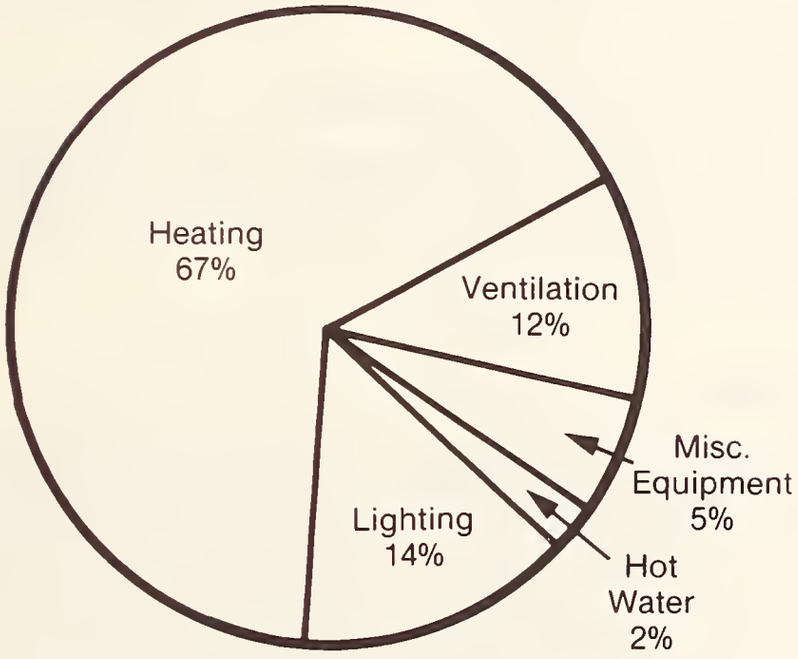
As these figures show, the heating, ventilation and air conditioning (HVAC) system is the biggest energy user in both warehouses and transit facilities, accounting for 73% of all energy use in the first case, and 83% of energy use in the second. Lighting and equipment are the next largest energy users. Hot water accounts for a very small portion of the energy load--only 2%--of the energy used at the base.

Figure 1
Energy Use in U.S. Warehouses & Storage Facilities



Source: **Handbook of Energy Audits**
(Atlanta: Fairmont Press, 1979)

Figure 2
Energy Use in Seattle Metro Bus Garage



Source: **Energy Conservation Handbook: A Step-By-Step Guide For Transit Facilities** Office Guide (Seattle: Seattle Metro, Sept. 1982)

Chapter 2

ENERGY MANAGEMENT TOOLS

Two basic energy questions face transit facility managers:

(1) How much energy am I using?

(2) How can I reduce this level of consumption?

This chapter covers each of those questions. Part 1 describes how several transit managers monitor energy consumption. Part 2 discusses some calculations--payback, present worth analysis, life cycle cost analysis--which transit managers can use to evaluate energy efficiency investments.

Energy Bookkeeping

Most transit managers don't know how much energy their buildings consume. Seattle Metro's energy management survey of 108 North American transit systems determined that 27% of the systems had no method for tracking energy consumption and costs, and only 40% tracked both energy consumption and energy costs. This may prompt the question--so what? Why should a busy transit manager bother to track energy costs? The answer is simple: it saves money. For example, a recent evaluation of federal energy conservation program for schools and hospitals found that institutions which monitored energy use saved more energy under the program than institutions which didn't monitor energy use.[2]

An energy bookkeeping system can help a transit system cut its energy bill in three ways. First, it helps make individuals accountable for utility costs. Many transit agencies split up energy management responsibilities; one division operates heating, lighting and air conditioning equipment, another division pays the utility bills. In this situation energy efficiency opportunities can get overlooked because no one is assigned the responsibility for keeping energy bills as low as possible. An energy bookkeeping system gives individuals the information they need to assume that responsibility.

Second, an energy bookkeeping system can help uncover billing errors. A small error like misplacing the decimal point while reading an electric meter can make a difference of thousands of dollars a month. A facilities manager at one large transit agency said that his energy bookkeeping system uncovers at least one error a month among the agency's 50 utility billing accounts.

Third, an energy bookkeeping system can pinpoint equipment problems. An energy tracking system used by the Greater Cleveland Regional Transit Authority identified a natural gas leak costing $20,000 a year and a water leak costing $29,000 a year.

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[2]The Synectics Group, The Manager's Guide To Successful Energy Conservation, (Washington D.C.: U.S. Department of Energy, 1983).

What steps are involved in setting up an energy bookkeeping system? How much time is involved? What kinds of information can a bookkeeping system provide? These questions can be answered by looking at the Toronto Transit Commission's experience with energy bookkeeping.

Energy Bookkeeping in Toronto: The Toronto Transit Commission developed its tracking system with the help of an energy consultant. The process works as follows: each month when utility bills arrive at the accounting department, they are photocopied and sent to the agency's plant engineer. This makes good sense from a cost control standpoint. The plant engineer is familiar with consumption patterns in Toronto's bases and can quickly spot billing errors.

The plant engineer does a number of things with the utility bills. First, the engineer sums up the bills for each building. This is necessary because a single building often has several different meters and so receives several bills. Then the engineer converts all energy units into British Thermal Units BTU's, using the following conversion values:

1 kwh electricity = 3,413 BTU's

1 therm natural gas = 100,000 BTU's

1 gallon No. 2 fuel oil = 140,000 BTU's

1 gallon No. 6 residual fuel oil = 160,000 BTU's

1 pound steam = 1,000 BTU's

For example, a building which used 5,000 kilowatt-hours of electricity, 2,000 therms of natural gas, and 1,000 gallons of heating oil would have consumed just over 357 million BTU's in one month (5,000 x 3413 + 2,000 x 100,000 + 1,000 x 140,000). By valuing energy in BTU's the engineer avoids the "apples and oranges" problem which results from trying to compare therms, kwhs and gallons.

Next the engineer divides the total number of BTU's consumed in a month by the total number of degree-days in the month. A degree-day (DD) is a number measuring the extent to which temperatures differ from 65 degrees during a month. Degree-day calculations are based on the theory that at 65 degrees a building's HVAC system is at perfect equilibrium. So, by dividing each month's consumption by the number of degree-days in the month, the engineer is able to factor out the effect of weather on energy use. Finally, the engineer plots the current BTU/DD number on a graph with BTU/DD numbers from prior months. This makes increases or decreases in energy consumption easier to spot. The entire bookkeeping process takes about two hours a month.

Some transit managers take the analysis one step farther and divide each building's BTU/DD figure by the total square footage of the building. The result--BTU's per square foot per degree day--allows a manager to evaluate the effect of a building expansion or renovation on energy consumption, or identify inefficient facilities which need attention.

Project Analysis

How should a transit manager decide among competing projects? Are storm windows a better buy than solar heating? Should an air-to-air heat exchanger or heat wheel or glychol loop be used to recover heat from exhaust air? There are three kinds of analysis which can help answer these questions: simple payback, present worth analysis and life-cycle cost analysis.

Simple Payback: Simple payback is the length of time it takes for a project to pay for itself. This is given by the following formula: simple payback = initial cost/annual energy savings. Here, for example, is the payback from adding air-curtain doors to a Toronto transit bus garage.

Payback on Air Curtain in Malvern Garage, Toronto Transit Commission

1. **Cost of Air Curtain: $10,000 per door**
2. **Annual Fuel Savings: $5,000 per door**
3. **Simple Payback = $10,000/5,000 = 2 years**

Source: T.T.C. Malvern Garage Energy Study, R.J. Black & Associates.

Payback is popular among transit managers because it is easy to calculate. A widely used standard is that a transit energy efficiency project is worth doing if it has a simple payback of less than three years.

Payback is a good way to evaluate projects which cost less than $10,000. These generally include high efficiency lights, lighting time-clocks, and setback thermostats. Payback analysis is also useful in situations which involve a planning horizon of less than 5 years. For example, it is a good way of identifying energy projects which are appropriate for an old building which will be demolished in a few years. Finally, payback analysis is a good way to evaluate a project's risk; the longer the payback, the greater the influence of assumptions about energy prices and inflation rates on a project's feasibility.

Simple payback has two disadvantages. First, it ignores the time value of money. Simple payback gives the same weight to all of a project's energy savings regardless of when they occur: $1 in savings in ten years is considered just as important as $1 in savings today. From an economic standpoint the two sums are not equal. $1 in savings today is more valuable because it can be invested to earn interest. The best way to reflect this fact is to "discount" or shrink future energy savings using compound interest techniques.

Second, simple payback ignores the effect of rising energy prices. Payback analysis values all of a project's energy savings at current energy prices. When the price of energy is rising, payback analysis underestimates the dollar savings from energy efficiency improvements.

There are several ways of overcoming the shortcomings associated with simple payback. For instance, an analyst can calculate an inflation-adjusted payback which determines how long it takes for a project's initial cost to be recovered when energy prices are escalating. This can be done using compound interest techniques except that future energy savings are compounded at a rate representing the above-inflation increase in the price of fuel. In the same way payback can be calculated using both an energy escalation rate and a discount rate. The choice of discount and energy escalation rates can have a significant effect on a project's payback. For example, a $150,000 energy efficiency project which saves $15,000 a year has a simple payback of 10 years. The payback increases to 13.9 years when a 5% energy escalation rate and a 10% discount rate are used.

Present Worth Analysis: Present worth analysis reduces all of the cash flows of an energy project to a single sum called net present worth. A project's net present worth equals the total discounted value of its fuel savings minus initial costs, maintenance costs, and replacement costs. This is given in the following formula:

Net Present Worth =

(Total fuel savings) - (Initial costs + maintenance costs + replacement costs)

If a project has a positive present worth, then it is an attractive investment. When a number of projects are compared using present worth analysis, the project with the greatest present worth should be chosen.

Table III shows the results of a present worth analysis of the feasibility of installing an $18,000 air-to-air heat exchanger in a bus garage in Fort Collins, Colorado. In column 2 of the table a portion of the project's initial or capital cost is assigned to each of its first 12 years. In column 3 each year's maintenance costs are estimated and adjusted for inflation. Annual capital and maintenance costs (column 4) are subtracted from annual energy savings (column 5) to determine the project's net annual savings (column 6).

Next, the annual savings are discounted to account for the time value of money. The project's annual net present worth (i.e., its annual worth in present value dollars) is shown in the last column. The project's total present worth after 12 years is $27,332. In Fort Collins, present worth analysis was used to compare a number of different energy efficiency projects. The results are shown in Table IV.

Table III

Present Worth Analysis For Air-to-Air Heat Exchanger
Transfort Garage (in dollars)

Fort Collins, Colorado

I Year	II Capital Cost[1]	III Maintenance Cost[2]	IV Total Costs	V Energy Savings[3]	VI Net Savings[4]	VII Annual Present Worth[5]
1984	2222	360	2582	3159	577	525
1985	2222	389	2611	3902	1291	1067
1986	2222	420	2642	4776	2134	1603
1987	2222	453	2675	5802	3127	2136
1988	2222	490	2712	7006	4294	2666
1989	2222	529	2751	8423	5672	3196
1990	2222	571	2793	9016	6223	3193
1991	2222	617	2839	9215	6376	2974
1992	2222	666	2888	9419	6531	2770
1993	2222	720	2942	9628	6686	2578
1994	2222	777	2999	9841	6842	2398
1995	2222	839	3061	10048	6987	2226
						$27,332

1. Based on $18,000 amortized at 12% interest for 30 years.
2. Based on 2% of initial system cost inflated at 8% a year.
3. Based on yearly natural gas savings inflated at approximately 12% a year minus the cost of electricity (required to operate the exchanger) inflated at 2% a year.
4. Expressed in inflated dollars.
5. Expressed in present value dollars using a 10% discount rate.

Table IV

Present Worth Analysis of Transfort Garage Energy Projects
Fort Collins, Colorado

	Initial Cost	12-Year Present Worth
1. Heat Exchanger	$ 18,000	$ 27,332
2. Passive Solar	10,824	-7,635
3. Active Solar Heating (small system)	28,866	-135,681
4. Active Solar Heating (large system)	512,900	-561,543

As Table IV shows, the air-to-air exchanger was clearly the best investment. In fact, each of the solar projects had a negative present worth--they were money losers--even after 12 years. On the basis of this analysis the city of Fort Collins decided to reject solar heating and to include heat recovery in its new transit building.

Life Cycle Cost Analysis: Life cycle cost analysis aggregates all equipment ownership costs into one sum. A project's life cycle cost (LCC) is the discounted sum of all the costs which occur during its lifetime. This is given in the following formula:

LCC = Investment costs + Maintenance costs + Replacement costs + Energy costs

When several projects are compared using LCC, the project with the lowest life cycle cost should be chosen. For instance, life cycle cost analysis was recently used to evaluate three different HVAC options for a bus storage building in Anchorage, Alaska. The three options were: (1) a standard HVAC system; (2) an HVAC system which ran at a reduced level during off-peak hours; and (3) an HVAC system which ran at a reduced level during off-peak hours and used heat wheels to recover waste heat from exhaust air.

The analysis assumed a 5% fuel escalation rate and an 8% inflation rate, so the energy costs and maintenance costs increased at an annual rate of 13% and 8% respectively. All costs were reduced to present value using a 10% discount rate.

Table V lists the initial cost, simple payback, and LCC of each option. The Municipality of Anchorage decided to install an HVAC with off-peak shut-down and heat recovery, due to the fact that it had the lowest life-cycle cost over the building's 20 year life. A poor investment decision would have been made if the HVAC systems were compared just on the basis of simple payback or initial cost. The regular HVAC had the lowest initial cost, but it was more expensive in the long-run than the other alternatives because it used more energy. An HVAC with off-peak controls had a quicker payback than an HVAC with off-peak controls and heat recovery, yet, it still wasn't the best choice because it had a higher energy bill. The HVAC with off-peak controls and heat recovery was the best choice because its life cycle cost ($0.9 million) was much lower than the life cycle costs of the alternative HVAC systems.

Table V

Life Cycle Cost Analysis of HVAC Systems
In Anchorage Transit Bus Garage

	Initial Cost	Simple Payback (in years)	Life/Cycle Cost
1. HVAC no controls	$404,250	--	$1,820,000
2. HVAC with off-peak shut-down	434,250	.62	1,120,000
3. HVAC with off-peak shut-down and heat recovery	525,000	4.64	906,000

Source: Building Energy Analysis Technical Memo; Kramer, Chin & Mayo, January 1983.

Present worth analysis and life cycle cost analysis are much more accurate than simple payback because they:

- **Account for energy price trends.**
- **Account for the time value of money.**
- **Evaluate a project on the basis of all its costs, not just on the purchase price.**

However, present worth and life cycle cost studies are both expensive and time-consuming. Most transit managers do not have the time or money to set up a computer model or hire a consultant to evaluate every energy-related project. Consequently, present worth analysis and life cycle cost analysis should be reserved for projects which cost more than $20,000 or have a life of more than 15 years or both. Good candidates for these analyses include: passive and active solar heating projects, HVAC systems, heat recovery systems, lighting systems, and proposals to provide internal circulation or reduce the number of overhead doors in a bus base.

Discounting

The biggest single error in many life cycle cost and present worth studies is that they use a zero percent discount rate. Discounting reduces streams of benefits to a single amount--called present value or present worth -- using compound interest formulas. The choice of a discount rate is important because it determines the rate at which future benefits will "shrink" as a result of the cost of money. For example, an energy efficiency investment which saves $10,000 a year for 10 years has a present value of $100,000 at the end of 10 years if a 0% discount rate is used. However, ten year present value shrinks to $77,214 if a 5% discount rate is used, or $61,442 if a 10% discount rate is used. Notice that an increase in the discount rate will decrease the present worth of a project.

The common rationale which is used to defend a zero percent discount rate is that transit facility construction funds amount to free money. There are no carrying costs in the form of high interest payments. UMTA provides 80% of the capital in the form of an interest-free grant; the other 20% of the capital can be easily raised by local governments through tax-exempt bonds or taxation. But from an economic standpoint neither the federal nor the local money should be considered free. If a local government issues tax-exempt bonds to provide the 20% match then the cost of those funds is the interest on the bonds. The discount rate should reflect this. If the 20% match is raised through local taxes it carries what economists call "an opportunity cost": it has been diverted from the private sector where it could have been invested to earn a market rate of return. In this case the cost of the money is equal to the interest which would have been earned if the money had been invested. UMTA construction grants also have an opportunity cost because they consist of money which has been diverted from the private sector to the federal government. In fact, the federal government recognizes this in evaluating energy investments in its own buildings. The U.S. General Services Administration (GSA) uses a 7% discount rate to evaluate energy projects proposed for federal buildings.

Chapter 3

THE HEATING VENTILATION AND AIR CONDITIONING (HVAC) SYSTEM

The HVAC system accounts for up to 75% of all energy use at most transit facilities. This is because transit facilities need lots of ventilation to remove bus exhaust, smoke and paint fumes from the air; and because transit facilities have lots of surface area, but little building core in which to store heat.

Transit systems can minimize HVAC energy waste if they:

- **Keep building temperatures low in the winter and high in the summer.**
- **Turn back thermostats when a building is unoccupied.**
- **Install tamper proof thermostats.**
- **Install local temperature controls.**
- **Recover heat from exhaust air.**

Building Temperatures

The easiest way to minimize energy waste is to make sure that temperatures are set at U.S. Department of Energy recommended levels when a transit building is occupied.

Table VI

U.S. Department of Energy Recommended Building Temperatures (Fahrenheit)

	Winter	Summer
Offices	68	78
Computer Rooms	65	65
Corridors	62	Uncontrolled
Mechanical Equipment Rooms	55	Uncontrolled
Storage	55	55

Source: Manual of Energy Saving in Existing Buildings & Plants #1, (Englewood Cliffs: Prentice-Hall, 1978, p. 58)

There is no need to heat transit buildings above 68° in the winter. A majority of the agencies in our survey keep office and maintenance area temperatures at 68°. Transit agencies in Sacramento and Santa Rosa, California; Springfield, Massachusetts; and Spokane, Washington, set maintenance area temperatures at 65°. Most transit agencies keep thermostats in bus storage areas at 50°. The Chicago Regional Transit Authority and St. Paul Metropolitan Transit Commission heat storage areas to 45°. Transit agencies which heat buildings above 68° in the winter are overlooking a big opportunity for energy savings--a building's heating bill can be reduced 8% by lowering the thermostat five degrees.

Turning Back Thermostats

Another easy way to cut energy waste is to turn back transit building thermostats during unoccupied hours. Here are some guidelines for setbacks:

Table VII

U.S. Department of Energy
Recommended Temperatures for Unoccupied Buildings

	Unoccupied Temperature
Offices	55°
Corridors	52°
Storage	50°

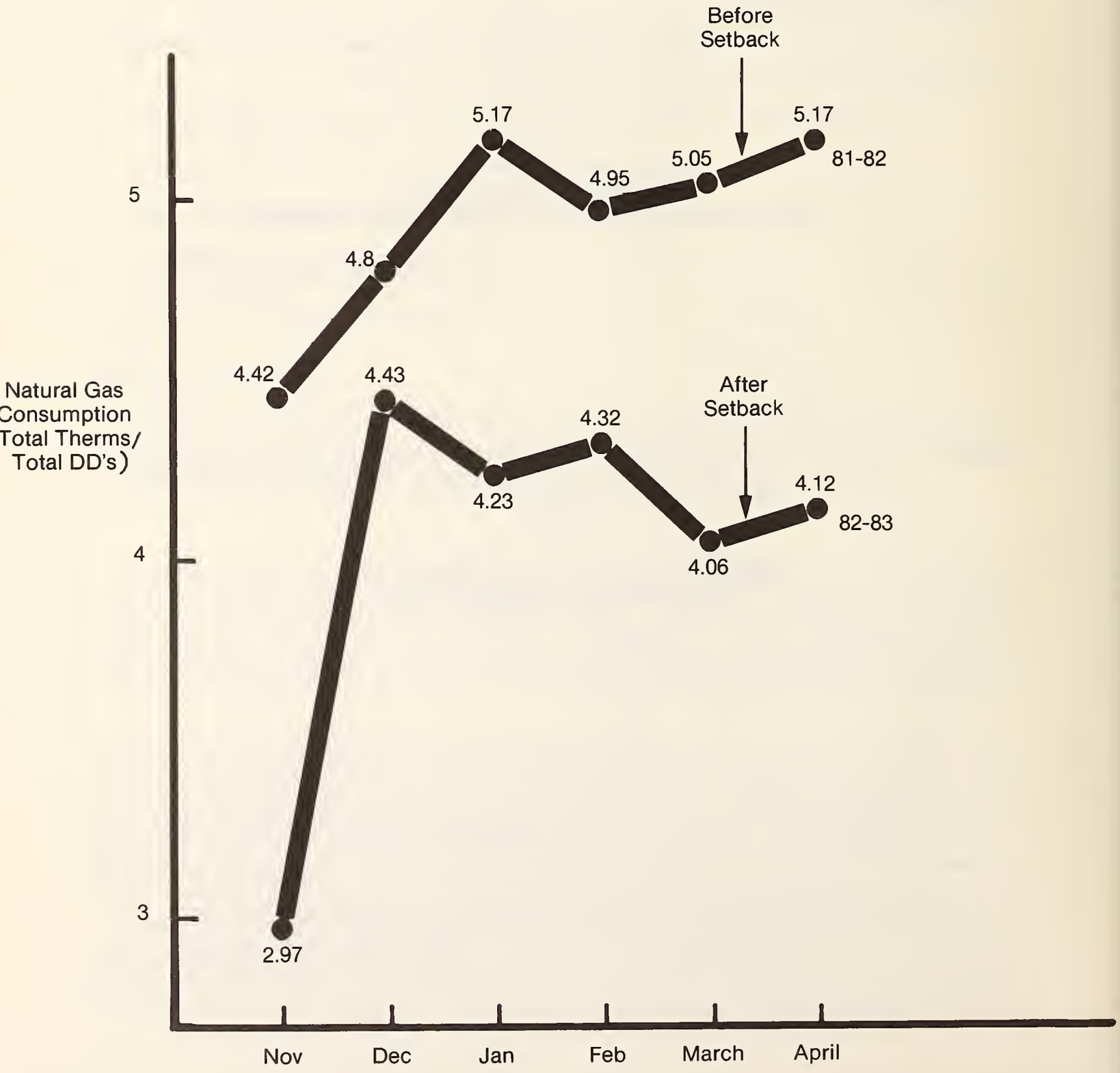
Source: Architects and Engineers, Guide To Energy Conservation, U.S. Department of Energy, Manual of Energy Savings in Existing Buildings and Plants #1 (Englewood Cliffs: Prentice-Hall, 1978, p. 58).

Transit offices and small bus garages which are unoccupied for 8 to 12 hours a day make good candidates for temperature turnbacks. Some transit systems turn back temperatures by hand. In Austin, Texas, a janitor turns off the heat in the Austin Transit System's buildings between 12 and 4 in the morning. A mechanic in a Springfield, Massachusetts garage switches off the heat in the bus storage area after the agency's bus fleet has left for the day.

Other transit systems control building temperatures by installing thermostats which are connected to timers. Setback thermostats are excellent energy investments. They cost only $100 apiece and usually have a payback of less than one year. The Bridgeport Transit District of Bridgeport, Connecticut cut energy use in one facility by 20% using setback controls. In 1982 Bridgeport installed a setback timer and tamperproof thermostats in a bus garage at a cost of $741. The timer was designed to set back the garage temperature by 15° between 10:00 pm and 4:30 am. Figure 3 compares the garage's natural gas consumption before and after the setback.

The effect of weather on heating bills has been factored out by dividing each month's natural gas consumption by the number of degree-days in the month. Over the entire heating season the garage's average natural gas consumption dropped from 5.17

Figure 3
Energy Savings from Installing Setback Thermostat in a Bridgeport Conn. Transit Garage



therms/degree day to 4.12 therms/degree day. At a 1983 natural gas price of $0.82 a therm the setback saved $4,668.58. This means that the setback timer paid for itself in about two months.

Setbacks can be effective in the summer as well as winter. The Oklahoma City Transportation and Parking Authority uses setback thermostats which raise office temperatures from 74° to 84° between 7:30 pm and 5:30 am in the summer.

The Ottawa-Carleton Regional Transit Commission uses timers in two garages to activate bus storage air handling equipment only during peak vehicle movement hours. When the timers at one garage broke down for 3 months, the heating bill increased by 15%.

Tamper-Proofing Thermostats

Thermostat-tampering is a problem in many transit buildings. Here are two examples: (1) The director of one northeastern transit system used to come into his garage on Sunday morning and find the temperature at 80°. His mechanics would get cold during the night, turn up the thermostats and then forget to set them back at closing time; (2) the facilities manager at one southwestern transit agency discovered that an elaborate time-clock temperature setback system wasn't producing any energy savings because employees had turned all time-clock settings to 70°.

Several transit systems have dealt with this problem by installing metal or plastic thermostat covers at a cost of $10-20 a box. Some systems have tried other approaches. One manager installed "dummy" thermostats which weren't hooked up. Another manager hid the thermostats. Other managers have installed central controls which over-ride local thermostats. Tamper-proofing may work for a while, but unless employees understand the importance of conservation, the boxes may be a waste of time. Even the best box is unable to withstand a screwdriver, hammer or coathanger.

Local Temperature Controls

Several transit systems have reduced their energy consumption without spending a dollar by cutting off heat where it's not needed. The Bridgeport Transit agency was able to turn off the gas in one bus storage facility for an annual savings of $1800.

A word of caution: Some systems have turned off the heat in storage garages and have had trouble with frozen pipes. Another, perhaps better approach is to isolate parts of a building for a shut-off. Metro Transit of Waterloo, Iowa for example, sealed off some little-used storage areas on the second floor of its building for use as a dead air buffer.

Many transit buildings don't have floor or room temperature controls. This can waste energy by forcing an HVAC system to condition an entire building in order to keep one room comfortable. In a northwestern transit building, heat pumps run non-stop despite the fact that 6 of the building's 7 floors are unoccupied at night and on weekends. Three floors and a basement of the Dayton Transit Company's building in Dayton, Ohio used to be air-conditioned just to keep one dispatcher's office cool on weekends. Dayton's transit manager installed a portable AC unit in the dispatch office, allowing him to turn off the rest of the building on weekends.

Heat Recovery

Transit garages are good candidates for heat recovery because they exhaust large amounts of heated but impure air. The 3 most common heat recovery devices are air-to-air heat exchangers, heat wheels, and run around loop exchangers. Each of these devices can be used to recycle "coolness" in the summer as well as "heat" in the winter.

Air-to-air heat exchangers: Air-to-air heat exchangers transfer heat by bringing exhaust and intake airstreams next to each other on either side of a thin metal or plastic plate. The plate allows heat to pass through, but prevents the two airstreams from actually mixing. Most air-to-air heat exchangers have efficiencies of 50% or less, that is, they usually transfer only 50% of the heat content of exhaust air to intake air. For example, on a 10° day with 60° exhaust air, the typical air-to-air heat exchanger would preheat make-up air to 35°.

Air-to-air heat exchangers are the best form of heat recovery for transit agencies which are concerned about maintenance costs. Air-to-air heat exchangers cost less initially than other heat recovery devices, and have lower operating costs because they do not require external power to operate, and have no moving parts which can wear out. However, air-to-air heat exchangers have two drawbacks. First, they are less efficient than heat wheels or run-around loops. Second, the exchangers work well in the winter, but not in the summer. A few transit agencies have tried using air-to-air exchangers to cool intake air; none have been pleased with the results.

Heat Wheels. A heat wheel or "thermal wheel" is a large disc stuffed with a porous, heat sensitive substance, usually aluminum or brass or stainless-steel mesh, which rotates over exhaust and intake air ducts. Each region of the wheel absorbs heat as it passes through the exhaust air stream and releases the heat as it passes through the fresh air stream. Heat wheels are the most efficient form of heat recovery; they salvage 60-80% of the heat from exhaust air. This makes them a good choice for transit buildings in cold climates. A heat recovery feasibility study in a Toronto Transit Commission bus garage found that heat wheels cost more initially than air-to-air exchangers or a run-around loop, but had a quicker payback because of higher operating efficiencies.

Heat wheels have three drawbacks. First, they have higher purchase and installation costs than air-to-air exchangers. Second, heat wheels have more moving parts than air-to-air exchangers or run-around loops; this makes them more expensive to maintain. Third, intake air can be contaminated with impurities from exhaust air since the wheel passes directly between intake and exhaust airstreams. This problem can be mitigated by adding a purge section to the wheel.

Run-Around Loop: A run-around loop differs from a heat wheel or air-to-air heat exchanger in that it uses fluid as a heat transfer medium. A run-around loop pipes antifreeze between two coils, one in the exhaust air stream, one in the intake air stream. The antifreeze absorbs warmth as it circulates through the exhaust coil air stream. Then it is pumped to the intake coil where it releases its heat. Run-around loops have one advantage over the other heat recovery devices: they can recover heat from exhaust air in one part of a building and transfer it to intake air in another part of a building. This makes run-around loops the only feasible heat recovery device in transit buildings where intake and exhaust air ducts are not adjacent to each other. The Denver RTD installed a run-around loop in one garage where intake vents and exhaust vents are 1,000 feet apart.

Run-around loops have two drawbacks. First, they have low efficiencies, usually between 40% and 50%. Second, they require quite a bit of maintenance. In Denver the fluid levels in the loop must be checked monthly and the coils in the exhaust and intake air streams must be cleaned 2 or 3 times each heating season. The Municipality of Anchorage, Alaska decided to use heat wheels instead of a run-around loop in a new transit garage because the coils in the loop were susceptible to frost buildup.

Table VIII shows the results of 6 studies on the feasibility of heat recovery in transit garages. It shows that heat recovery equipment is a good energy investment even though it is expensive. The initial costs of installing a heat recovery system varied from $28,000 in a small garage like Fort Collins to $200,000-300,000 in the larger garages. But each project had a simple payback of 10 years or less.

Table VIII

Feasibility Studies of Transit Building Heat Recovery

Transit Agency	Type of System	Cost	Simple Payback
Seattle, WA	Heat Pipes	$ 62,790	2.09 years
Anchorage, AK	Heat Wheels	$121,000	4.64 years
Syracuse, NY	Air-to-air	$220,000	5.1 years
Fort Collins, CO	Air-to-air	$ 28,000	6.45 years
Denver, CO	Glychol Loop	$225,000	8 years
Toronto, Ontario,CN	Heat Wheels	$200,000	10 years

TO ELIMINATE HVAC ENERGY WASTE

- **keep building temperatures below 68°**
- **install setback thermostats**
- **install thermostat covers to prevent tampering**
- **install air-to-air heat exchangers, heat wheels, or a run-around loop to recover heat from exhaust air**

Chapter 4

THE BUILDING ENVELOPE

The building envelope--a building's walls, roof, and floors--has a large effect on energy consumption in sprawling one-story transit garages, which have significant surface area but little internal space in which to generate and store heat. This means that in transit garages, envelope improvements are often the best energy "buy." The envelope is less important in multi-story transit administration buildings because they have more internal space in which to hold heat. In administration buildings, envelope improvements are not as important as projects which improve the efficiency of lighting or ventilation systems. Transit agencies can do four things to minimize heat loss through the building envelope:

(1) Install devices which limit infiltration through overhead doors—this is the single best way to reduce heating bills in existing transit garages.

(2) Build new garages with fewer overhead doors.

(3) Install radiant heating.

(4) Weatherstrip, caulk, and insulate.

Devices Which Limit Door Infiltration

Infiltration--the leakage of outside air into a building through openings in the building envelope--is the largest source of heat loss in transit garages, due to the fact that large overhead doors are frequently left open during the heating season. For example, 90% of the annual heating load of a new transit garage in Chapel Hill, North Carolina is due to heat loss through large overhead doors. An energy study of a Metro Transit garage in Seattle, Washington determined that if the garage's 19 service bay doors were left open for 14 hours each day, then they would have a heat loss of 12,162 billion BTU's per year. That equals 70% of the building's natural gas consumption or $52,000 of the building's $75,752 annual gas bill.

The devices which various transit systems have tried to reduce overhead door heat losses are: strip curtains; air curtains; and automatic doors controlled by wands, electric eyes or magnetic loop switches.

Plastic Strip Curtains: Strip curtains consist of 4-6 inch strips of plastic which are hung to cover overhead door openings. This study identified 14 transit agencies which had experimented with plastic strips. Three agencies still use strips while the others have switched to air curtains or automatic doors. The strips are inexpensive ($300-400/door for thin strips, $1100-1200/door for thick strips), but impractical. First, they damage buses by bending mirrors and pulling off signal lights. In Anchorage the strips knock 2 or 3 signal lights a week off buses. Some transit systems have had to instruct drivers to come to a complete halt halfway through the curtain to prevent snarling. Second, the strips don't hold up. They catch on mirrors or bus edges

and snap off. In cold climates they freeze and become brittle. In Boston a plastic strip curtain lasted only 3 days. In Anchorage strip curtains have to be replaced twice a year. Third, the strips can pose a safety hazard as they become scuffed up and visibility drops.

Air Curtains: Air curtains are the best device for reducing heat loss through heavily travelled garage entrances and exits. Air curtains cut infiltration by blowing warm air across overhead door openings. Several systems have wired air curtains to overhead doors so that the curtains operate whenever the doors are open. A Denver Regional Transit District garage has a curtain which comes on whenever the outside temperature drops below 50°. One advantage of air curtains is that they allow buses unobstructed passage into a building--there is no danger of a bus ramming an air curtain if the system isn't working. A second advantage is that they are easier to install in existing garages than automatic doors.

However, air curtains have two disadvantages. First, they are more expensive than other anti-infiltration devices, with costs varying from $4,000 to $15,000 per door. Second, some of the energy savings of an air curtain are offset by the fact that the curtain's heating coil and fan run on electricity. A study of the feasibility of putting an air curtain in one Pittsburg bus garage found that the curtain would consume 3 million BTU's of energy each year, although it still resulted in an annual net savings of several hundred dollars.

Automatic Doors. Automatic doors can be activated by wands, electric eyes, or magnetic loops. A wand system activates an overhead door when a bus pushes back a wand hanging from the roof of a garage. Wand systems cost less than air curtains, but are unreliable. Transit agencies in Edmonton, Alberta; Toronto, Ontario; and Detroit, Michigan have had trouble with buses breaking wands. In St. Paul, Minnesota, wands slipped off the top of buses. The wind activated a wand system in Portland, Oregon. All but two of the transit systems which have tried wands have switched to electric eyes or magnetic loops. Electric eye or photo-cell doors consist of a pair of electronic eyes which face each other from each side of a door entrance. As a bus approaches the entrance it breaks the beam between the two eyes and activates the door. The door is usually programmed to close again if nothing else breaks the beam within 30 seconds.

Photo-cell doors cost less than air curtains, and they can't wear out like plastic strips. However, they are extremely sensitive. In Denver and Portland, Oregon electric eye systems failed when the eyes were bumped out of alignment. One overhead door in Edmonton cycles continuously between 4 and 4:30 each afternoon because the sun's rays strike the electric eyes directly. Electronic eyes have been triggered by fog in Anchorage, by snow in Denver and Niagara, New York, and by bus reflectors and logos in Pittsburg. Magnetic loops are the best device for reducing heat loss through doors which handle moderate amounts of bus traffic, such as entrances to maintenance bays and service lanes. A magnetic loop system uses a couple of wires embedded in the pavement to trigger overhead doors. One wire is placed outside the doors and the other wire is placed just inside the doors. When a bus crosses the first wire it trips a relay which opens the door. When the bus crosses the inside wire it trips another relay which closes the door. Magnetic loop systems cost approximately $2500 a door. They have an advantage over photo-cells because they don't trigger as easily. Still, a couple systems have had trouble. In Columbus, Ohio traffic lights tripped the magnetic loop switches. Portland, Oregon has switched from a magnetic loop system to a manual system because the magnetic doors were too sensitive--they triggered doors every time a bus drove within 10 feet of a building.

Automatic Doors and Accidents. Some transit systems have had trouble with buses running into bay doors. For example, last year, one Midwestern transit agency reported $120,000 in damage to the automatic doors in its six garages. One cause of accidents is equipment failure--a door may simply fail to open as a bus approaches. A more common source of accidents is operator error. Some drivers have caused accidents by attempting to race behind another bus into a building before the 30 second cycle is up. Other drivers have miscalculated the time that it takes for a door to open. In an effort to deal with this problem at least two systems--Syracuse and Dayton--have installed traffic lights at entrances and require drivers to wait for a green light before entering the building.

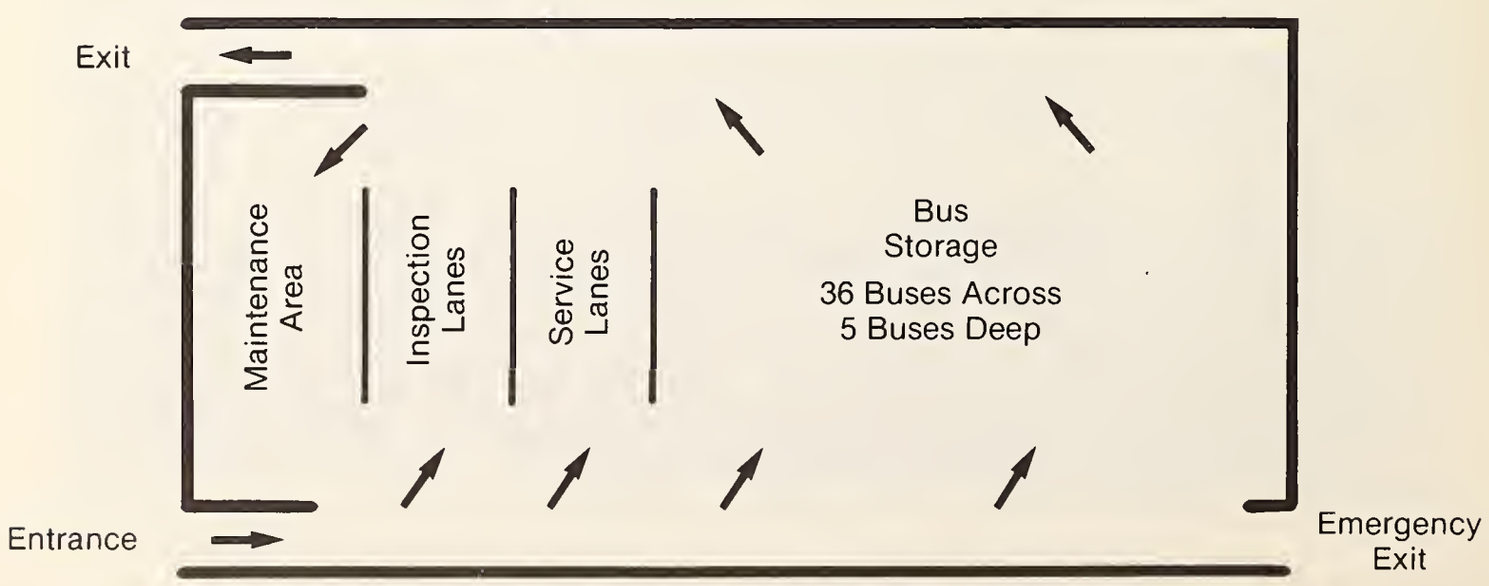
Other Devices: Two other devices are worth mentioning. Des Moines, Iowa installed a TV monitor and a remote control door switch in its dispatch office. This allows dispatchers to close doors which have been left open. In five years of operation there has been just one accident.

The Ottawa-Carleton Regional Transit Commission has received a $150,000 grant from the provincial government to build a 69 foot bus vestibule in front of the main entrance to one of its garages. The vestibule will have interlocked doors (i.e., the back door must shut before the front door opens), and it will be kept just above freezing in winter. The vestibule will create a dead air space to reduce infiltration every time a bus enters the garage.

Limiting Bay Doors

The simplest way of reducing infiltration losses is to eliminate as many overhead doors as possible. Many new transit facilities in the northeast or midwest are designed to allow internal circulation. Figure 4 illustrates the way internal circulation works at a 250-bus facility in Denver.

Figure 4
Bldg Floor Plan
RTD East Metro Garage, Denver, Colo.



The building has one entrance door, one exit door and one emergency door. Buses can move from storage to maintenance to fueling once they are inside. Internal circulation isn't the only energy-saving feature of the envelope. The entrance and exit doors are located on the same side of the building to prevent a wind tunnel effect from occurring when the doors are open. Both doors have air-curtains which operate when the outside air temperature drops below 50°. Finally, the building's exterior walls and roof extend beyond the doors. This creates a thermal transition area between the outside and the inside.

Several transit managers feel that internal circulation has resulted in substantial decreases in energy use. The Ottawa Regional Transit Commission's newest garage—which has several energy efficiency features including internal circulation--uses 15% less energy per square foot than an older garage which has no energy efficient features. The Metropolitan Transit Commission of St. Paul, Minnesota reduced annual fuel bills $35,000 by moving into a new garage with internal circulation.

A study of the economics of internal circulation in a Syracuse, New York bus garage determined that internal circulation had a 5.9 year simple payback. Internal circulation increased the cost of the garage by $690,000 since additional floor space was needed. However, internal circulation saved $117,000 a year in heating bills because it meant that the garage was able to function with only 3 overhead doors instead of 15. The study cited a number of other advantages of internal circulation including increased comfort, reduced maintenance costs, and enhanced security.

Radiant Heating

Internal circulation may not be feasible in transit buildings located in moderate climates. When this is the case, the next best thing is to install radiant heating. Radiant heaters warm objects, not air. A garage equipped with radiant heaters will lose less heat through overhead doors than a garage with conventional space heating, because inside air can be kept 10° cooler. Many transit agencies hang gas-fired radiant heaters from garage ceilings. Tri-Met of Portland, Oregon installed a row of radiant heaters along each side of the inspection pits in its maintenance garage. Air entering the garage is heated only to 55°. The radiant heaters provide the rest of the heat directly at work stations. A study in a Toronto Transit Commission Garage determined that a $25,000 radiant heating system would pay for itself in five years through reduced heat loss.

There are two drawbacks with radiant heating. First, radiant heaters are of no use if people constantly change work stations. Second, in very cold climates, radiant heaters will not provide enough heat by themselves if bay doors are left open for extended periods of time. The Ottawa-Carleton Regional Transit Commission and the Toronto Transit Commission had to supplement radiant heating systems in maintenance garages with air curtains to maintain comfort levels.

Weatherstripping, Caulking, Insulation

Double-paned windows, insulation and weatherstripping may be good ideas, but they are rarely the most effective energy efficiency measures in transit buildings. Double--paned windows don't have much effect on consumption because windows constitute a very small percentage of a transit garage's exterior walls. Insulation retrofits are

rarely cost-effective except when a roof is replaced. The benefits of storm windows and insulation disappear quickly if bus bay doors are left open. In the words of one facilities manager, "I try to direct my efforts towards controlling the on-time of machines and the HVAC. Caulking and weatherstripping aren't too helpful because there's a 400 square foot hole in the building every time a door is left open."

TO REDUCE ENERGY LOSSES THROUGH THE BUILDING ENVELOPE

- **Install air curtains on doors which get lots of traffic and magnetic loops on other doors**
- **Design new garages to allow internal circulation**
- **Install radiant heating to allow lower air temperatures**

Chapter 5

LIGHTING AND EQUIPMENT

Most energy studies identify lighting as the second largest energy user in commercial buildings. In a Seattle, Washington transit facility lighting and equipment accounts for 14% of all energy consumption. Lighting is especially important for transit facilities which have small heating needs. Transit agencies can reduce lighting and equipment energy waste in transit facilities by:

- **Removing excess lights**
- **Switching to high efficiency lights**
- **Turning off lights when they aren't needed through the use of local switches, timers, or dimmers**

Removing Lights

Uniform lighting is inappropriate in most transit facilities and can waste as much as 50% of all lighting energy. Table IX provides lighting level guidelines for transit facilities. These guidelines are based on Illuminating Engineering Society (IES) industrial standards, federal government standards for public offices, and actual lighting levels in energy efficient transit facilities.

Table IX

Recommended Lighting Levels For Transit Facilities

Area	Lighting
General Office	70-100 Footcandles
Maintenance Shop	50-80 Footcandles
Bus Storage Areas	20 Footcandles
Aisles, Corridors, Stairways	5-10 Footcandles
Parking Lots	1 Footcandle

Although many older buildings have lighting loads which amount to 3 to 8 watts per square foot of floorspace, recent studies suggest that buildings can be adequately lit at 2 watts per square foot. Some transit buildings have done even better than that. A new operations and maintenance building in Chapel Hill uses 1.63 watts per square foot. A new garage and office building in Syracuse uses only 1.5 watts per square foot.

The simplest way to reduce lighting waste is to remove excess lights. In 1979 the Des Moines Metropolitan Transit Authority of Des Moines, Iowa took out every other light in its administrative offices. A recent energy audit of a transit administration building in the Northwest discovered that the building used 3 watts of lighting per square foot. Lighting levels inside the building averaged 120 footcandles. The transit agency will cut interior lighting levels from 120 footcandles to 80 footcandles by removing two of the four fluorescent lamps in each ceiling fixture. Delamping could cut the agency's lighting bill by as much as half, and it will also reduce the air-conditioning load--a 1 kwh decrease in lighting consumption leads to a 0.5 kwh decrease in air conditioning consumption. The Massachusetts Bay Transportation Authority has saved $200,000 a year by removing half of the fluorescent lamps in its subway tunnels.

Another way to reduce lighting waste is to replace existing lights with smaller lights. For example, the Dade County Office of Energy Management replaced the 40-watt fluorescent lights in Dade County Metrobus' administrative offices with 34-watt "energy-savers." This reduced the energy consumption of each lighting fixture by 17%, with a payback of 2 years. An energy audit of a Northwestern bus garage determined that if low-wattage fluorescent lamps were installed, the annual lighting bill could be cut by $6,200 with a payback of 2.4 years. If low-wattage lamps were installed over time as existing lamps burned out, the retrofit would have a simple payback of 0.5 years.

Switching To High Efficiency Lights

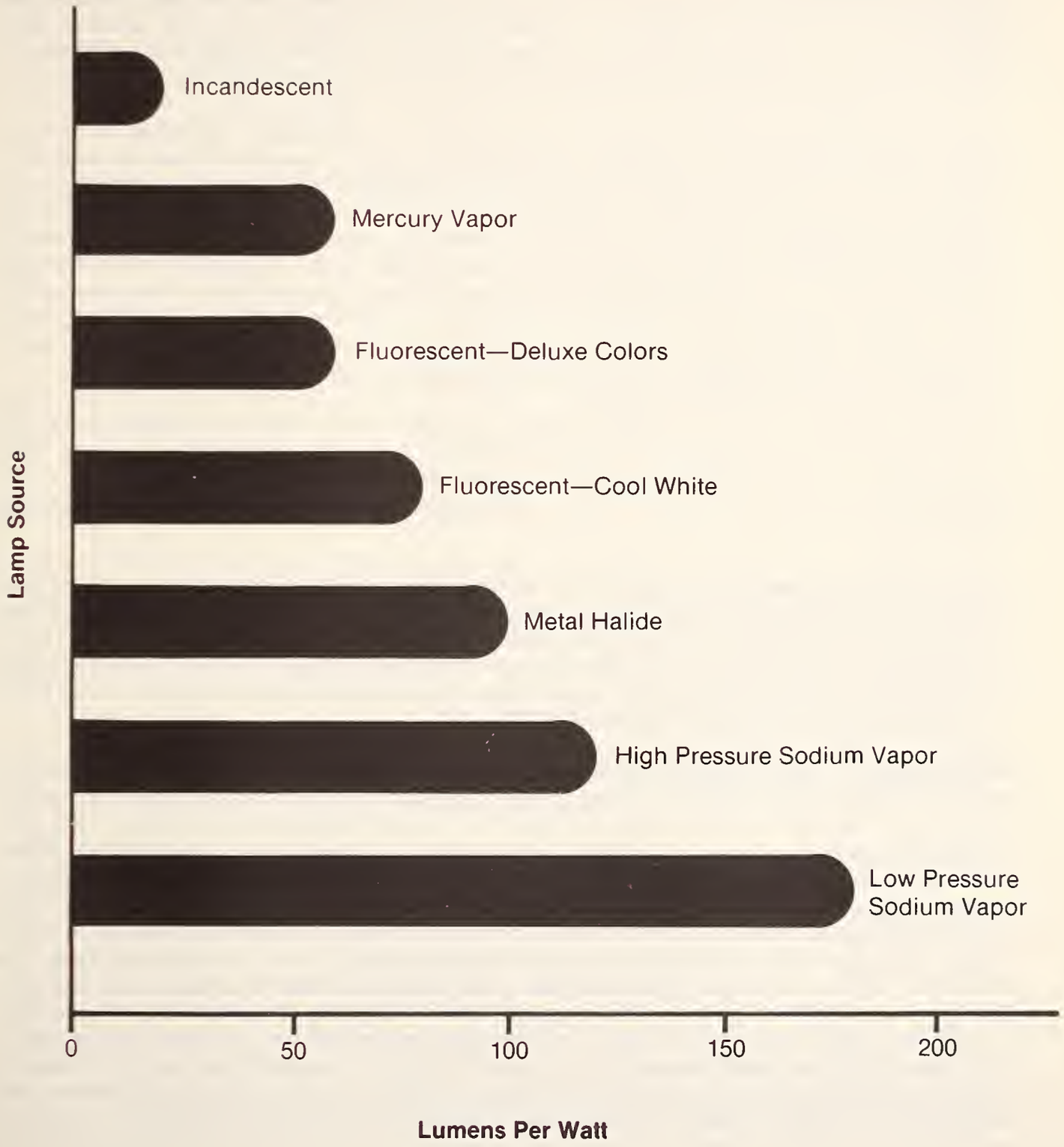
Here are some lighting recommendations for transit facilities based upon current practices at new transit facilities.

Table X

Efficient Light Sources for Transit Facilities

Area	Best Lighting Source
General Office	Fluorescent
Aisles, Corridors, Stairways	Fluorescent
Maintenance Shop	Metal Halide
Bus Storage Areas	High Pressure Sodium
Parking Lots	High Pressure Sodium

Figure 5
Efficiencies of
Various Light Sources



Source: Energy Management Workbook,
Seattle City Light

Figure 5 shows the efficiencies of the different light sources. Low pressure sodium lights are the most efficient, followed by high pressure sodium lights, metal halide lights, mercury vapor lights, and incandescent lights.

Fluorescent Lights: Fluorescent lights are the best choice for transit offices. They cast a high quality light and are 3-4 times more efficient than incandescent lights. Incandescent lights are popular in transit offices because they are inexpensive. However, the low purchase price is deceptive; incandescent lights have higher life cycle costs than fluorescent lights because they burn out quicker and use more energy.

In transit buildings incandescents are a good light for storage closets and bathrooms. For any other use, fluorescent lights are a better choice. A recent federal government study found that if a commercial building is equipped with incandescent lights, a conversion to fluorescent lights would save more energy than any other single energy retrofit. Santa Rosa Transit was able to convert from incandescent to fluorescent lighting by replacing twenty-four 75 watt incandescent lights in a maintenance building with twenty-four 15 watt fluorescent lights at a total cost of $240. The fluorescent lamps reduce consumption by 9,409 kwh's annually, or $588--this means that the retrofit had a payback of about three months. The Massachusetts Bay Transportation Authority has replaced 12,800 passenger station incandescent lights with fluorescent lights.

Fluorescent lights are a poor light source in maintenance and bus storage areas for two reasons. First, they are weather-dependent. As the temperature drops their light output drops. Second, fluorescent lights are less efficient than high-intensity discharge lights (mercury vapor, metal halide, and high pressure sodium) at illuminating large rooms.

High Pressure Sodium: High pressure sodium lights are the best choice for lighting bus storage areas and parking lots. They are tremendously efficient, they last a long time, and they take only a couple minutes to re-light or "re-strike" after being turned off. High pressure sodium lamps are used in the bus storage areas of transit garages in Anchorage, Alaska; Ames, Iowa; Appleton, Wisconsin; Denver, Colorado; Columbus, Ohio; Syracuse, New York; and Dayton, Ohio.

Metal Halide: Metal halide lights are the best choice for lighting bus maintenance bays and maintenance shops. Metal halide lights are a little less efficient than high pressure sodium lights, and they can take up to 20 minutes to restrike. However, metal halide lamps throw a "white" light which has good color rendition qualities; high pressure sodium lamps throw a "gold" light which makes it hard to distinguish colors. The mechanics at one transit property which experimented with high pressure sodium lights had trouble telling the difference between red and blue wires. Several transit agencies have been able to reduce their energy bills by switching from low efficiency lights to metal halide lights. The Saginaw Transit System of Saginaw, Michigan was able to reduce the average size of lighting fixtures in a new garage by 44% by using metal halide lights rather than low-efficiency mercury vapor lights. The Transportation Department of the city of Everett, Washington reduced the lighting load in one transit garage to 5 kilowatts from 15 kilowatts by replacing 253 fluorescent lamps with 15 large metal halide lamps. The retrofit improved lighting levels and saved the city $3,000 a year.

Lights Which Run Too Long

There is a hard and fast rule concerning incandescent lights: always turn them out

when leaving a room. But that rule doesn't hold for the other kinds of lights.[3] It can take 10 minutes or more for a metal halide or mercury vapor lamp to restrike once it has been turned off. And, while a transit manager can cut his or her energy bill by turning off lights, the savings are offset by the fact that frequent re-striking causes lamps to burn out sooner. Fluorescent lamps have a break-even point (i.e., a point where energy savings begin to outweigh costs associated with lamp stress) of 5 minutes. In other words, fluorescent lights should be turned off whenever a room is vacated for more than 5 minutes. The break-even point for mercury vapor or metal halide or high pressure sodium lamps occurs later; they should be turned off whenever a room is vacated for 30 minutes or more. Here are two examples of transit agencies which pay unnecessarily high lighting bills because they fail to turn off lights. An energy audit of one four-story transit administration building in the Northwest revealed that one-fourth of the lighting load was wasted due to the practice of leaving all building lights on between the time that the building was vacated (5:30) and the time that the janitors finished cleaning (2:30). The audit concluded that maintenance should be rescheduled to coincide with working hours, or that switches should be installed to allow janitors to turn off lights in areas which had been cleaned.

An energy audit of another Northwest transit facility--where all lights were left on continuously--determined that the annual lighting bill could be cut by $16,000 if extra switches were installed to allow the facility's personnel to turn off lights in unoccupied areas.

Transit Agency Experience With Light Control

There are several things that transit agencies have done to insure that lights stay off when they aren't needed. Bi-State Transit of St. Louis has placed special stickers on all light switches which should be turned off at night. The Utah Transit Authority and the Miami Valley Regional Transit Authority (Ohio) use energy management computers to control lights. Syracuse Centro in New York has timers which turn off half of its storage area lights when buses leave in the morning. The Columbus Area Transit System of Columbus, Missouri installed skylights along with a dimmer-switch which turns down lights on sunny days. The dimmer-switch system cost $150,000 and has a 2.5 year payback. A similar system has also been installed in a transit facility owned by Ames Transit of Ames, Iowa.

A number of systems use timers or photo-cells to control exterior lights and parking lot lights. The Denver Regional Transportation District uses a timer to "step down" parking lot lighting to a level of 1 footcandle thirty minutes after the last bus arrives. At dusk a photo-cell turns the lights off. The process reverses in the morning; at dawn the lights come on to a 1 footcandle level. Thirty minutes before the first bus the lights are "stepped up." When the sun gets strong, the lights turn off.

Most lights are subject to lumen depreciation. As they age, their light output decreases. Tri-Met of Portland, Oregon installed a "dimmer" system in one transit garage which saves energy by adjusting fixture current levels to offset lumen depreciation. When the building's metal halide lamps are new, and their lumen output is high, the system reduces the flow of electricity to each fixture; this dims the lights and saves energy.

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[3] Rita Harrold, "Lighting," in Energy Management Handbook (Englewood Cliffs: Prentice Hall, 1982) p. 415.

As the lamps age, and their lumen output deteriorates, the system increases the flow of electric current to each fixture. The dimmer system cost $162,000. It has a 3.4 year payback if it is assumed that electricity prices will increase by 20% a year, and a 5.9 year payback if it is assumed that electricity prices will increase by 10% a year.

Summary

Lighting energy efficiency projects fall into three classes:

(1) **Low cost projects which have immediate paybacks in all transit buildings**

(2) **Moderate cost projects which are cost-effective in some transit buildings but not in others**

(3) **High cost projects which are cost-effective only in new transit buildings**

Low cost projects: Two low cost projects are delamping and lamp replacement. Delamping reduces utility bills and maintenance costs at no additional capital cost. Lamp replacement can be done with little extra expense if a transit agency adopts a policy of substituting low-wattage energy-saving lamps for existing lamps which have burned out, provided that they are compatible with existing ballasts.

Moderate cost projects: Moderate cost projects include things like installing local switching, installing fluorescent lights in transit offices, and installing metal halide or high pressure sodium lights in transit garages. The projects usually have costs of $500-$10,000, although lighting retrofits can cost up to $50,000 in a large transit facility. Moderate cost projects will be cost-effective, that is they will have a payback of less than 3 years, in buildings where lights run continuously, incandescent lamps are used for office lighting, fluorescent and mercury vapor lamps are used for garage lighting, or electric rates are above 7¢ per kwh.

High cost projects: Energy management computers and sophisticated lighting dimmer systems have costs of $100,000-$500,000. Even so, they can have paybacks of less than five years if they are installed in new buildings which will be occupied continuously, or are subject to high electric rates. The cost of retrofitting computer controls or a dimmer system into an existing building can be prohibitive.

TO ELIMINATE LIGHTING WASTE

- **Reduce lighting levels to 2 watts per square foot of floorspace by removing lights**
- **Replace existing lights with smaller-wattage energy-efficient lights**
- **Switch from incandescent to fluorescent lighting in office areas**
- **Switch from mercury vapor to metal halide or high pressure sodium lighting in maintenance and bus storage areas**

- Install local switches to improve control over existing lights
- Investigate the use of daylighting and "dimmer systems" in new buildings

Chapter 6

HOT WATER HEATING

Hot water accounts for a very small portion (2-3%) of transit building energy use. There are two major sources of hot water waste: excessive water temperatures, and uninsulated pipes or storage tanks.

Excessive Water Temperatures

In most transit facilities, domestic hot water is used primarily for hand-washing. Many transit systems heat domestic water to 150° even though several recent energy studies recommend 90-105° domestic hot water temperatures. Several transit agencies have been able to save money by turning down hot water temperatures. Tri-Met of Portland, Oregon; the Utah Transit Authority of Salt Lake City, Utah; and Santa Rosa Municipal Transit of Santa Rosa, California have dropped domestic water temperatures to 120°. The Southeast Area Transit agency of Norwich, Connecticut and Syracuse Centro of Syracuse, New York have dropped domestic hot water temperatures to 105° and 100° respectively.

Heat Loss

Heat losses from uninsulated storage tanks and pipes can be surprisingly large for two reasons: (1) most hot water systems operate 24 hours a day, so heat loss occurs continuously rather than just when a building is occupied; and (2) there is a large temperature difference between hot water and the surrounding air. Even though storage tanks are located inside, the temperature difference can equal 30-40° when domestic water temperatures are set above 100°. As the temperature difference increases, the rate of heat loss increases.

An energy audit at a garage operated by Metro Transit of Seattle, Washington estimated that an uninsulated hot water storage tank was boosting electric bills by $281 a year (assuming a 105° hot water temperature and 70° indoor air temperature). Further, the audit estimated that a project to add two inches of insulation to the storage tank would pay for itself in 2.6 years.

TO ELIMINATE HOT WATER WASTE

- **Reduce domestic hot water temperature settings to 105°**
- **Insulate hot water pipes and storage tanks**

Chapter 7

RECENT INNOVATIONS TO HELP CONSERVE ENERGY

Aside from solar energy and traditional conventional energy projects there are three things that transit agencies can do to improve energy efficiency: install computers to control equipment; burn crankcase oil to provide heat; and use chassis dynomometers to generate electricity. This chapter discusses each of these innovations.

Energy Management Systems

An energy management system (EMS) is a computer system which controls and monitors energy use. Six transit agencies have installed EMS's--the Utah Transit Authority of Salt Lake City, Utah; the Denver Regional Transportation District of Denver, Colorado; the Miami Valley Regional Transit Authority of Dayton, Ohio; the Transit Authority of Northern Kentucky of Fort Wright, Kentucky; and the Metropolitan Transit Authority of St. Paul, Minnesota, and the Transportation Department of Anchorage, Alaska. At least two other properties--the Ottawa Regional Transit Commission of Ottawa, Ontario, Canada, and the Southeastern Michigan Transit Authority of Detroit, Michigan--will install EMS's in the near future.

An EMS consists of the following components: (1) Sensors which record data on building conditions and equipment operations; (2) a control console consisting of a keyboard, screen, and microprocessor; (3) cables which transmit signals from sensors to the microprocessor; and (4) software programming. Transit systems use EMS's to perform the following tasks: energy monitoring, start/stop scheduling, load-shedding, and duty-cycling.

Energy monitoring. A large EMS can have up to 200 sensors which record information on building temperatures, energy loads, and equipment. The Denver Regional Transit District's EMS stores information on solar collector temperatures, solar storage tank temperatures, and air temperatures. The Utah Transit Authority's (UTA) EMS records inside and outside temperatures, HVAC start-ups and HVAC shut-offs, as well as data on which bus block heaters are running.

Start/stop scheduling. An EMS can perform two kinds of start/stop routines. First, it can execute simple commands, such as, "turn on lights at 9 a.m.," "turn off lights at 5 p.m." The UTA controls the infrared heaters in its bus garages this way. Second, an EMS can execute "optimization" programs in which the operator sets parameters (e.g. occupancy hours, acceptable temperatures) and allows the EMS to make start/stop decisions. The UTA uses a computer to "optimize" HVAC operations in its administration building. Every afternoon the EMS monitors indoor and outdoor temperatures, and turns off the HVAC as early as possible while maintaining temperatures in a 68-75° comfort zone. It has turned off the HVAC 80 minutes early under favorable weather conditions.

Load-shedding. Transit agencies pay electric bills which are garaged on two things: monthly consumption in kilowatt-hours, and peak monthly demand in kilowatts. A transit agency which pays demand charges of more than $5.00 per kilowatt can save thousands of dollars in demand charges by programming an EMS to turn off equipment

during periods of high demand. The UTA, for example, identified 2 blowers, 14 fans, and 3 compressors in one maintenance complex as low priority loads. It entered the list of low-priority loads into its EMS along with maximum and minimum off-times for equipment, and instructions on how to shed and retrieve loads. The EMS turns off the low priority equipment when the building's electric demand is at its peak. It saves the UTA $7,436 a year in demand charges. A load-shedding program also saved the Miami Valley Regional Transit Authority of Dayton, Ohio $1200 in 1980.

Duty cycling. Duty cycling routines turn off heating or ventilation equipment and allow a building to "coast" for short periods of time during the day. The UTA uses its EMS to duty cycle ventilation units and radiant heaters in two buildings. Duty cycling has one drawback: it can shorten equipment life. Motor driven equipment overheats when it is shortcycled, hence the importance of developing accurate maximum/ minimum parameters. However, duty cycling may be worthwhile even if it shortens equipment life, because energy costs are rising faster than equipment costs, so the energy savings from duty cycling may offset the costs associated with reduced equipment life.

How much money can an EMS save? Here are the results of an economic analysis of the UTA's EMS. It was installed in a 4 building complex in 1982 at a cost of $225,000. In its first year the EMS cut the UTA's average peak load by 7%, it improved the UTA's power factor by 20%, it reduced electricity consumption by 15% and it reduced the UTA's natural gas consumption by 19%.[4] Table XI shows that the annual savings from the EMS is $38,182. The EMS has a simple payback of 5.89 years.

Table XI

Annual Savings from Installing Energy Management Computer in Utah Transit Authority Meadowbrook Complex

	Savings
Reduced Demand Charges	$ 7,436
Improved Power Factor	$ 4,800
Reduced Electricity Charges	$15,968
Reduced Gas Bills	$ 9,978
Total Savings	$19,141

$$\frac{225,000}{38,182} = \textbf{5.89 year simple payback}$$

[4]Calculations contained in Appendix IV.

EMS's are expensive; purchase and installation costs for a large transit facility vary from $20,000 to $50,000 depending on the sophistication of the EMS and the size of the building. Still, an EMS may be feasible if the following conditions exist:

- **utility bills equal at least $100,000 a year,**
- **electric demand charges are high,**
- **a building is occupied continuously,**
- **or a building has a complex heating and ventilation system.**

A transit building which is occupied only from 9 to 5 is a poor candidate for an EMS--a $25.00 setback thermostat can accomplish just as much at a fraction of the cost. But if a building has both solar and conventional heating, or if it contains administrative offices, a drivers lounge, a maintenance garage, and a storage area--and each area has separate temperature and ventilation requirements--then an EMS may be cost-effective.

Waste Oil Heating

Seven transit agencies--Centro of Syracuse, New York; the Utah Transit Authority of Salt Lake City, Utah; the Montreal Urban Community Transit Administration; Intercity Transit of Olympia, Washington; the Duluth Transit Authority of Duluth, Minnesota; and the Transit Department of the city of Anchorage, Alaska--burn waste oil to heat transit facilities. A number of other transit agencies have boilers which can be converted to burn waste oil. Waste oil heating makes good economic sense. It triples the salvage value of used oil: transit systems sell used crankcase oil to recyclers for 25 to 40 cents a gallon; that same oil is worth $1.18 a gallon if it displaces its equivalent in fuel oil, or $0.86 a gallon if it displaces its equivalent in natural gas.[5]

Waste oil heating is a great energy investment. Syracuse Centro saves $10,000-15,000 a year by heating its administrative offices with used crankcase oil. The Utah Transit Authority installed four waste oil heaters in a transit maintenance building and one waste oil heater in a bus wash building at a total cost of $25,000. In their first 3 months of operation, the waste oil heaters have cut natural gas consumption in the UTA's Meadowbrook complex by 53%. This winter the waste oil heaters should save $26,988 in gas bills, with a payback on the initial investment of less than 1 year.[6] The UTA is so pleased with the performance of the heaters that it plans to install 6 more waste oil heaters in other buildings.

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[5]Based on average fuel prices of 1.18/gallon for heating oil and $0.55/therm for natural gas. Monthly Energy Review, U.S. Department of Energy, July 1983.

[6]Calculations contained in Appendix V.

Heating Administrative Offices: Waste oil can be used to fire individual space heaters, or a central boiler. Syracuse Centro uses waste oil to fire the boiler that heats its administrative offices. After crankcase oil is removed from buses, it is inspected and oil which is too badly contaminated with anti-freeze and water is discarded. The remaining oil is poured through a wire mesh screen into a basin which drains to an underground storage tank. The oil passes through a filter made of dirty rags just before it enters the storage tank. Next, the oil is piped to another tank where it is mixed with fuel oil which makes it burn better. The oil then passes through another filter just before it is burned. Last year, Centro burned between 10,000 and 14,000 gallons of waste oil.

Small Space Heaters: The Utah Transit Authority and the Metropolitan Transit Authority of Duluth, Minnesota burn waste oil in small space heaters. Crankcase oil is drained into underground storage tanks. From there it is pumped to space heaters suspended from the ceiling of bus garages. The heaters burn between .5 and 1.5 gallons of waste oil per hour. In both cases the heaters are backed up by conventional heating systems.

Small waste oil heaters have three advantages over waste oil fired boilers. First, the small heaters are subject to fewer pollution regulations than boilers. Under current pollution regulations, a transit agency wishing to burn waste oil in small heaters must obtain an operating permit in 21 states. But in order to burn waste oil in its central boiler that same transit agency would have to obtain an operating permit in 44 states.[7] If the U.S. Environmental Protection Agency limits waste oil burning in the future it will almost certainly exempt small heaters.

Second, small heaters require less fuel than boilers. A transit facility with 100 buses might generate 2,000 gallons of waste oil a year--not nearly enough to fire a central boiler which requires 10,000-20,000 gallons of fuel. But 2,000 gallons could fire a medium sized waste oil heater, or 2 small waste oil heaters. Several transit systems decided against waste oil burning after determining that they couldn't generate enough waste oil to keep a central boiler running. A manager at the Southeastern Michigan Transit Agency of Detroit, Michigan equipped a boiler for conversion to waste oil, but was unable to actually make the switch when the agency increased the length of time between oil changes. The Montreal Urban Community Transit Administration trucks waste oil from several garages to the garage which burns it.

The third advantage small waste oil heaters have over waste oil fired boilers is that they are designed to supplement, rather than replace, conventional heating systems. This means a garage still has heat if the waste oil heaters break down. If a transit garage burns waste oil in a conventional boiler, and the boiler goes out, the garage's pipes could freeze up.

Caveats: Waste oil heating saves a lot of money, but it can be a headache unless the right precautions are taken. There are a number of things which can go wrong. First, waste oil which is contaminated with water, antifreeze or gasoline can damage burners. Once, as a result of a storage tank leak, the Utah Transit Authority pumped water instead of oil into each of its heaters, which had to be shut down for three days for repairs. On another occasion the Authority had to shut down its waste oil heaters for ten days after burning a batch of waste oil which was badly contaminated

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[7] John Yates & Associates, The Operational and Environmental Effects of Burning Unprocessed Used Oil, (Wash., D.C.: Wash. Assoc. of Petroleum Re-Refiners, June 1973, p.6-34)

with gasoline. The Metropolitan Transit Authority of Duluth, Minnesota had to replace the burner tips on its space heaters after burning a batch of waste oil which was badly contaminated with gasoline.

Second, dirt and metal shavings can clog filters or burners. Waste oil plugged up the burner and filters in one Mid-western transit agency's boiler after just 15 minutes. A Northeastern transit agency stopped burning waste oil because its burner kept clogging.

Third, waste oil can cause pumps to wear out prematurely because it is more abrasive than fuel oil. Finally, waste oil can lower a boiler's efficiency by coating the inside of a boiler with ash, especially if it is burned in a boiler which is designed for No. 2 heating oil.[8] There are three simple rules for transit agencies which want to minimize equipment problems with waste oil burners.

Rule #1: Don't burn waste oil in a boiler without modifying the boiler to handle it. Don't burn waste oil in a boiler unless that boiler is already capable of burning residual (No. 6 diesel or "bunker") oil. Even then, waste oil fired boilers require special burners and filters.

Rule #2: Keep the quality of waste oil as high as possible. Transit agencies which successfully burn waste oil do everything possible to remove its impurities. They discard waste oil if it looks contaminated with water or antifreeze. They install extra screens and filters and replace them 3-4 times a year. A few systems blend waste oil with other flammable liquids. The Southeastern Michigan Transit Authority blends 1 part diesel fuel with 20 parts waste oil to make the waste oil burn better. Syracuse Centro blends waste oil with regular fuel oil.

Rule #3: Maintain the equipment. Waste oil heaters and boilers require more servicing than conventional heating equipment. The Utah Transit Authority cleans its waste oil heaters once every three weeks during the heating season. The Duluth Metropolitan Transit Authority inspects its heaters every day.

Dynamometers

Two transit agencies--Syracuse Centro and the Ottawa-Carleton Regional Transit Commission of Ottawa, Canada--have chassis dynomometers which can be used to generate electricity. When a bus's rear wheels turn the dynomometer cylinder, the dynomometer's motor acts as an electric generator and feeds electricity back into the building's power grid. The electric savings can be substantial. If a shop uses a 150 horsepower dynomometer for 2 hours a day it can generate 51,000 kilowatt-hours of electricity in a year's time. This would save $2,550-6,000 a year depending on local utility rates.

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[8] Ibid. pp. 5-5 to 5-12

INNOVATIVE WAYS TO SAVE ENERGY IN TRANSIT FACILITIES

- Install an Energy Management System if:
  - utility bills equal $100,000 a year
  - electric demand charges are high
  - a building is occupied 24 hours a day
  - a building has 2 or more HVAC systems
- Retrofit residual oil-fired boilers to burn waste oil
- Install waste oil space heaters where an existing boiler is not equipped to burn heavy oils.
- Make sure that chassis dynomometers in new facilities can be used to generate electricity.

Chapter 8

SOLAR ENERGY

There are two types of solar energy systems: active and passive. Active systems distribute the sun's energy within a building using mechanical devices such as pumps and fans. Passive solar systems distribute the sun's energy by relying on natural forces, such as radiation (the transfer of heat via heat waves), convection (the transfer of heat by the motion of air), and conduction (the transfer of heat through a solid mass).

This study identified 17 transit properties which used solar energy for space heating or domestic water heating or both. As Table XII shows, 7 properties used solar energy for active space heating, 8 properties used solar energy for passive space heating, and 6 properties used solar energy to heat domestic water.

Solar Heating Economics

Active solar heating is a poor investment in transit facilities. This study identified 6 transit systems which determined that active solar heating wasn't economically feasible: Transfort of Fort Collins, Colorado; the Transportation Department of the City of Chapel Hill, North Carolina; the Central Ohio Transit Authority of Columbus, Ohio; Metro Transit of Waterloo, Iowa; Centro of Syracuse, New York; and the Topeka Metropolitan Transit Authority of Topeka, Kansas.

To be a good energy investment, a solar project should have a payback which is significantly less than its useful life. Solar heating equipment has a useful life of 20-25 years. Two of 8 active solar transit projects which were examined had estimated paybacks of less than 15 years; 3 had estimated paybacks of 15-20 years; and 3 projects had estimated paybacks of more than 20 years. In nearly every case, the payback estimate appears to have been too short. There are three reasons for this:

Underestimated Maintenance Costs: Several payback studies assumed that annual maintenance costs would equal .5 - 1.0% of a solar project's initial capital cost. Most transit facilities managers felt that this estimate was much too low, and that actual annual maintenance costs could run as much as 5% of the system's initial capital cost.

Inaccurate Assumptions About Fuel Prices: Several of the solar payback studies overestimated the size of fuel price increases. For example, one payback study assumed that the price of natural gas would increase at an above inflation rate of 10% a year through 1996. The current U.S. government's forecast for that region is much more cautious, predicting annual natural gas price increases of 9% from 1981 to 1986, 0% from 1986 to 1990, and 1.6% beyond 1990. If the U.S. Government's estimates are used in place of the 10% a year escalation rate, then the payback on this particular solar project increases from 18 years to 25 years.

No Discounting Was Used: None of the solar payback studies discount future dollar savings to reflect the time value of money. This overvalues the future benefits associated with solar heating. The 3 solar projects in the 15 to 20 year category turn out to have actual paybacks of nearly 30 years if they are evaluated using a 7% discount rate.

Table XII

Solar Projects At 17 Transit Properties

	Agency	Active Solar	Passive Solar	Solar Hot Water
1.	Ames Transit Agency Ames, IA		X	
2.	Transportation Department Amsterdam, NY	X		X
3.	Valley Transit Appleton, WI		X	
4.	MBTA Boston, MA			X
5.	Transportation Department Chapel Hill, NC		X	X
6.	RTA Chicago, IL		X	
7.	RTD Denver, CO	X		X
8.	Valley Transit Derby, CT	X		
9.	Transfort Fort Collins, CO			X
10.	Transportation Department Greeley, CO	X		
11.	Transit Management Co. Laredo, TX		X	
12.	Transportation Department Middletown, OH	X		
13.	SEAT Norwich, CT	X		X
14.	Transit Authority City of Omaha Omaha, NB		X	
15.	Berkshire Regional Transit Authority Pittsfield, MA		X	
16.	Tri-Met Portland, OR	X		
17.	Metropolitan Transit Authority Waterloo, IA		X	
		7	8	6

Some passive solar projects are good investments in transit facilities, others are not. Windows and skylights are poor energy efficiency investments in transit facilities. Nearly everywhere in the continental United States, south-facing windows admit more energy than they lose, but the energy savings are usually not large enough to make the extra cost of the windows worthwhile. The glass-block wall and skylight in Chapel Hill's transit facility save $2,080 in heating and lighting bills a year, but the wall and skylights added $91,000 to the cost of the building. The payback on the wall and skylights is close to 40 years even when fuel prices are assumed to increase at a rate of 10% a year. A study conducted on a Fort Collins, Colorado transit building found that passive solar projects--clerestory windows and a south-facing glass wall in the maintenance area--had paybacks of close to 40 years even when fuel price increases had been taken into account. A third project--administrative office skylights--actually increased the building's energy use.

Passive solar trombe walls are a much better buy. Trombe walls in Waterloo, Iowa and Appleton, Wisconsin transit facilities have paybacks of 7.5 and 21.4 years assuming a 10% annual fuel escalation rate.

Solar Hot Water Heating Economics

Solar hot water heating is cost-effective only if a transit building has an active solar heating system, or heats water with fuel oil or electricity, and is located in an area which gets lots of winter sunshine. Two studies of transit solar water heating are available. In a Preston, Connecticut bus garage, a $6,800 solar water heating system had a payback of less than 5 years because it was piggybacked onto an existing solar heating system. In a Fort Collins, Colorado bus garage a $7,100 solar water heating system had a payback of more than 25 years.

We calculated paybacks for a solar domestic hot water system sized to provide 100 gallons of hot water a day--enough water for 50 employees--at a transit facility in 8 U.S. cities. The analysis used U.S. Department of Housing and Urban Development data on collector sizes and energy savings, U.S. Department of Energy data on fuel prices, and 1981 industry cost estimates of $50-60 per square foot of collector space. Table XIII shows the results. Solar hot water heating has a payback of under 10 years only in El Paso, Texas. Moreover, in all 8 cities solar water heating has a payback of more than 20 years if it replaces a natural gas fired hot water boiler, with an average payback of 39 years.

Table XIII

Domestic Solar Water Heating
Simple Paybacks (in years)

If Electricity Is Displaced		If Natural Gas Is Displaced		If Fuel Oil Is Displaced	
El Paso	9	El Paso	26	El Paso	9
Los Angeles	11	Los Angeles	27	Denver	10
Denver	12	Denver	28	Los Angeles	13
Boston	14	Seattle	35	Des Moines	14
Des Moines	15	Boston	42	Atlanta	15
Wash., D.C.	18	Wash., D.C.	46	Wash., D.C.	16
Atlanta	20	Des Moines	50	Boston	19
Seattle	51	Atlanta	56	Seattle	21

Sources: Hot Water From the Sun (Wash., D.C.: U.S. Dept. of Housing and Urban Development, 1980); Life Cycle Cost Manual For The Federal Energy Management Program (Wash. D.C. National Bureau of Standards, U.S. Dept. of Commerce, May 1982); Solar cost estimates obtained over phone from Solar Energy Industries Association, Wash., D.C.

Active Solar Heating

Active solar heating systems consist of the following components: (1) rooftop collectors made of glass and metal which convert the sun's rays into heat; (2) a large metal tank in which heat is stored for use when the sun isn't shining; (3) a heat transfer fluid (usually antifreeze) which travels through piping loops between the collectors and the storage tank; and (4) computer controls which regulate the pumps and valves that direct the flow of heat between the collectors, the storage tank, and the building.

It is rarely feasible for a solar system to meet a building's entire heating load; a system with the storage and collector capacity to do that would be prohibitively expensive. Consequently, most solar heating systems are designed to provide 50-60% of a building's heat: the rest of the heat is supplied by a conventional back-up furnace.

The attitude of transit personnel towards solar energy is reflected in the following comments of a facilities manager for the Denver RTD: "Buck for buck I think that heat recovery systems are a better buy than solar. They are cheaper to control. And a heat recovery system pays off in about half the time that solar does. If I had a choice I'd opt for a heat recovery system."

Table XIV summarizes the performance of 8 transit solar heating projects. Five of 8 transit properties with active solar heating have had problems involving faulty controls, poor workmanship, or leaks.

Faulty controls. Solar controls are more complex than conventional heating controls so there is a greater chance that something will go wrong. Five transit properties have had trouble with solar controls. The most common problems were: failure to store heat for use at night, failure to make the right decision regarding when to use solar and when to use the back-up boiler; and an inability to make slight temperature adjustments in order to preserve building comfort levels.

Poor Workmanship. An additional problem with solar energy is that many contractors have had little experience with solar heating systems. Two transit properties have had trouble because the people hired to install solar equipment lacked the expertise to do the job correctly.

Leaks. In Denver a leak developed when vibrations worked loose a pipe carrying collector fluid into a heat exchanger. The collector loop had to be drained to fix the leak. It cost $5,000 to re-fill the loop with antifreeze. The Southeast Area Transit Agency in Preston, Connecticut experienced several 25-30 gallon spills when a relief valve opened in order to relieve pressure which built up in the collector loop due to an improperly designed control system.

Table XIV

Cost and Operating Performance of Active Solar Projects

System	Cost	Comments
RTD Denver, CO.	$ 900,000 $1,200,000 $1,200,000	Control Problems Leaks, Thermal Stress
SEAT Preston, CT.	$ 300,000	Control problems
Transportation Dept. Greeley, CO	$ 280,000	Works well
Transportation Dept. Amsterdam, NY	$ 40,000	Works well
Valley Transit Derby, CT	Not available	Control problems; now in litigation
Transportation Dept. Middletown, OH	$ 35,000	Works well

Passive Solar Heating

The most common passive solar projects in transit facilities are skylights, windows, south-facing glass and solar trombe walls.

Skylights, windows, glass walls. Skylights and a glass block wall provide 45% of the space heating needs in a transit facility operated by the city of Chapel Hill, North

Carolina. The building has 4,000 square feet of south-facing glass. The south wall of the building is made of heavy-duty glass block panels, the bus bay doors located on the southside of the building are glazed, and the building has a saw-toothed roof with several rows of southfacing skylights. Heat from the sun is stored in the building's 12' concrete walls and 6' concrete slab floor. Overheating, a problem with many direct gain solar projects, is minimized due to the self-shading properties of the glass block walls--they let sunshine into the building during the winter when the sun is low in the sky, but screen out the sun in the summer when it is at higher altitudes. An attractive feature of direct gain solar projects is that they provide light as well as heat. In Chapel Hill the glazing has eliminated the need for artificial light during the day in 65% of the building.

Trombe Walls

Trombe walls consist of a large sheet of clear glass or fiberglass suspended over an exterior wall with a southern exposure. A trombe wall, in effect, functions as a large solar collector. The sun passes through the clear glazing and is absorbed in the wall's surface. This heat is recovered by circulating air through the space between the wall and the glazing. Transit garages are good candidates for trombe wall heating, because they often have lots of wall surface with a southern exposure, and their walls are made of concrete, a good heat storage material.

Metro Transit of Waterloo, Iowa uses a trombe wall to provide 25% of the heating needs of the bus storage area in its maintenance facility. The southwest wall of the facility has been painted black and covered with one-quarter inch fiberglass panels. There is a sensor in the wall which activates four fans when the sun raises the temperature of the wall's surface above 50 degrees. The fans draw cold air through ducts at the bottom of the wall and blow warm air back into the garage through ducts at the top of the wall. Four gas-fired space heaters keep the storage area at 50° when the sun isn't out. Metro Transit originally became interested in a trombe wall because of its simplicity. To quote Metro's manager, "All you need for a trombe wall is an empty space, a piece of plastic, a black wall, and a blower." The trombe wall cost $30,000. A consultant's study estimated that it would have a 7.5 year payback.

Solar Domestic Water Heating

The RTD of Denver, Colorado; the Southeast Area Transit Property of Preston, Connecticut; and the Transportation Department of the city of Amsterdam, New York have incorporated solar water heating into active solar heating systems. This can be done simply by piping domestic water through a heat exchanger along with fluid from the collector loop.

Two transit agencies--MBTA of Boston, Massachusetts and Transfort of Fort Collins, Colorado--have "stand alone" domestic water heating systems. The domestic systems are similar in design to solar heating systems except that water from the solar storage tank is used to preheat domestic water. Both systems are operating reliably.

INVESTIGATE THE FEASIBILITY OF SOLAR TROMBE WALL HEATING IF A TRANSIT FACILITY HAS:

- Several hundred feet of south facing masonry wall
- Bus storage areas which can use low temperature solar heat

INVESTIGATE THE FEASIBILITY OF SOLAR WATER HEATING IF A TRANSIT FACILITY:

- Gets lots of winter sunshine
- Uses electricity or fuel oil to heat hot water

Chapter 9

NEW BUILDINGS

The energy intensity of new buildings grew between World War II and 1973, primarily because architects and facilities engineers were concerned only with minimizing initial building costs. But the energy price increases of the 1970's have changed things. Now emphasis has switched from initial costs to life-cycle costs. Many new buildings use 60% less energy per square foot than buildings constructed prior to 1970. This increase in efficiency is demonstrated by the fact that total energy consumption in U.S. residential and commercial buildings remained constant between 1976 and 1980 even though there was an increase in total square feet.[9]

The trend towards energy efficiency is also apparent in new transit facilities. Our research identified 18 transit buildings which had just been finished or were under construction at the time of this report. These new buildings have the following energy saving characteristics:

- **Siting which accounts for the effects of the sun and wind**
- **Building envelopes which minimize heat loss**
- **HVAC systems which recover heat or minimize HVAC requirements**
- **Use of the sun as a light source**

Facility Siting

In the northern hemisphere the south side of a building gets the most exposure to the sun, and the north side, the least. In addition, the north and west sides of a building are most subject to cold winds.[10] There are a number of ways that transit buildings have been designed to account for the effects of the sun and wind. Two new buildings in Ames, Iowa and Appleton, Wisconsin are situated so that their largest wall faces south--this gives the Ames facility 210 feet of southern exposure and the Appleton facility 350 feet of southern exposure. In both cases the south wall is not a conventional wall, but a passive solar trombe wall. In effect, the entire south face of each building is used as a solar collector. The trombe wall in Ames should provide 160 million BTU's of energy a year or one-sixth of the total heating needs of the bus storage area. Finally, the Ames building has an earth berm (a series of stepped planters rising from the ground out to window height) against the north face of the building to protect it from cold winter winds.

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[9] Energy Efficiency of Buildings in Cities, (Wash., D.C., Office of Technology Assessment, U.S. Congress, March 1982), p. 28.

[10] Fred Dubin, Energy Conservation Standards for Building Design Construction & Operation (New York: McGraw-Hill, 1978).

Another innovative siting measure involves placing all bus entrance and exit doors on the south side of a building to take advantage of the sun, and to eliminate the "wind tunnel" effect which occurs when doors are open at each end of a building.

The Central New York Regional Transit Authority had an industrial engineering team review plans for its new garage and office facility to figure out how work processes and workers could be combined to keep space requirements to a minimum. As a result of this analysis, the facility's size was reduced from 235,000 square feet to 182,000. This not only reduced the building's construction cost, but it reduced future heating and ventilation costs as well.

The Building Envelope

The biggest single way to reduce heat loss in a transit facility is to limit the number of overhead doors, through the use of internal circulation. Internal circulation is a standard feature in new buildings which are located in the Northeast and Midwest. Insulation is important, especially when the heat losses from infiltration have been minimized. And, there is another consideration: it is always cheaper to build energy efficiency into a building than to attempt to retrofit it in later. Insulation is cost-effective when included in a building's original construction plans; insulation retrofits are rarely cost-effective (the payback is usually beyond 10 years) unless a wall or roof must be torn down anyway.

The HVAC

As previously mentioned, transit facilities are good heat-recovery candidates because they need large amounts of makeup air. Most new facilities include heat wheels or a glychol loop as part of their HVAC system. Again, the maxim holds: it is cheaper to build efficiency into a building than to retrofit efficiency in later.

The ventilation systems in many new bus facilities are much more flexible than conventional ventilation systems. Denver's East Metro facility is a good example. Its ventilation system has two settings: a high setting (6 air changes per hour) for periods of peak bus traffic; and a low setting (2 air changes per hour) for off-peak periods.

The Transportation Department of the city of Anchorage has an HVAC system which reduces ventilation rates by 50% during periods of minimum occupancy, from 1.5 cubic feet per minute (cfm) per square foot of storage area during peak hours to .75 cfm per square foot of storage area during off-peak hours.

Lighting

New transit buildings typically have some or all of the following lighting features. First, energy efficient lights, such as high pressure sodium lights in storage areas, metal halide lights around maintenance bays, and fluorescent lights in offices. Second, they make extensive use of natural lighting. This has been accomplished in a number of buildings by using glass blocks as a wall or roof material. The entire south face of a Chapel Hill, North Carolina transit operations and maintenance building consists of 8 inch glass blocks. The glass wall, and 1800 square feet of skylights have eliminated the need for artificial lighting during the day in the building's maintenance bays,

service lanes, and machine shop. In the rest of the building, artificial lights are used only for task lighting during the day.

A new bus maintenance facility for Ames Transit of Ames, Iowa has 20 insulated skylights in the bus storage area. The facility's storage area lights are controlled by a photo cell, which turns on lights whenever the skylights fail to provide enough illumination. One of the Omaha Transit Authority's bus garages has a skylight system consisting of six 400 by 18 solar panels mounted into the roof at a 60° angle. The panels make up less than 10% of the roof but provide all of the daytime lighting in the bus storage area.

TO ELIMINATE ENERGY WASTE IN NEW BUILDINGS

- **Site buildings so that the largest wall faces south.**
- **Investigate the feasibility of a passive solar trombe wall.**
- **Provide internal circulation for buses in cold climates.**
- **Recover waste heat from exhaust air.**
- **Provide skylights for daylighting.**

Chapter 10

GETTING ORGANIZED TO IMPLEMENT ENERGY SAVING MEASURES

Transit agencies have tried at least two different approaches to energy management. Some agencies have set up an energy management team. For example, the MBTA and Washington, D.C. Metro have created energy offices. The town of Middletown, Ohio has created an energy committee consisting of the town's Maintenance Supervisor, Director of Public Works, and Director of Purchasing. The committee meets quarterly to discuss potential energy projects, and is staffed by a graduate intern from a local university. All of Middletown's energy projects have originated in the ad-hoc committee, including an active solar heating system in the town's bus garage.

Other transit agencies delegate the responsibility for energy management to a single individual. The Utah Transit Authority's energy management program is the responsibility of a facilities manager who has a great interest in energy efficiency. Syracuse Centro's Director of Purchasing has been designated as the agency's official energy manager. The Southeastern Michigan Transit Authority of Detroit, Michigan; the Ottawa-Carleton Regional Transit Commission of Ottawa, Canada; and the Toronto Transit Commission have assigned energy management responsibilities to engineers. The Baltimore Metropolitan Transit Authority and the Greater Cleveland Regional Transit Authority have assigned energy management responsibilities to transportation planners.

The success of an energy management program doesn't appear to depend on whether the program is given to an individual or a team. Some agencies, like the UTA have done well with the individual approach; other agencies like Middletown have done well using a team approach. However, all of the successful transit energy management programs have the following characteristics: (1) one person, one office or one committee is clearly held responsible for energy management; and (2) someone closely monitors energy use and investigates any sudden changes in consumption.

Resources

There are five sources of help for the transit manager interested in energy efficiency: UMTA, the U.S. Department of Energy, local energy offices, electric utilities, and private energy consultants.

UMTA - UMTA funds 80% of the cost of energy efficiency equipment in new buildings as part of its Facilities Construction Grants Program. The grants have helped finance energy conservation measures such as: internal circulation, heat recovery devices, high-efficiency lights, trombe walls, active solar heating, energy management computers, and waste oil heaters. UMTA regional engineers are a good source of information about what innovative energy projects have been included in new transit facilities.

U.S. Department of Energy - The U.S. Department of Energy's Institutional Conservation Program (ICP) will pay 100% of the cost of conducting a transit building energy audit (an analysis of energy consumption patterns and low-cost conservation

opportunities), or 50% of the cost of conducting a technical assistance energy study to evaluate the economic return on high cost conservation measures. The city of Middletown has received approximately $40,000 in ICP funds for energy audits and technical assistance studies. However, one caution is in order: there is often no need to pay a private consultant to do an energy audit, many electric utilities will do free audits.

Local energy offices - State government energy offices are important resources because the U.S. Department of Energy's Institutional Conservation Program funding is channeled through them. Local government energy departments can also be good sources of help. For example, the Dade County Office of Energy Management replaced all of the 40-watt lights in Dade County Transit's buildings with 34-watt energy-savers.

Electric utilities - Most electric utilities provide free energy audits for large commercial customers. It is in their interest to do so because by providing audits and encouraging customers to save energy, utilities can avoid expensive power plant construction programs. Portland General Electric recently audited Tri-Met's administrative building in Portland, Oregon. Last year the Province of Alberta audited two buildings for Edmonton Transit, of Edmonton Alberta. The Austin City Electric Department has conducted free audits for the Austin Transit System. Houston Power and Light does free energy audits for the Metropolitan Transit Authority of Harris County, in Houston, Texas.

Private energy consultants - Architects and engineers can assist transit managers by conducting life cycle cost studies, energy audits, and technical assistance studies. Often a small consultant's fee can produce a large drop in energy consumption. Bi-State Transit of St. Louis hired a consultant to help reduce energy bills in six old bus garages. Bi-State directed the consultant to look for energy conservation measures with a one year payback, because several of the older garages would soon be vacated. Bi-State Transit paid the consultant $50,000, using funds which had been budgeted for utility expenses. The consultant conducted walk-through audits of the garages, identified a number of low-cost conservation opportunities, and installed setback thermostats. In the year after the consultant finished work, Bi-State saved $115,000 in utility bills.

Chapter 11

CONCLUSION

This report has identified three types of projects which can help transit managers reduce energy bills: (1) low cost projects with immediate paybacks; (2) moderate cost projects with paybacks of less than 5 years; and (3) high cost projects with paybacks of less than ten years.

Low Cost Projects

Low cost projects have capital expenses of less than $1,000, and involve changes in facility operations and maintenance procedures. Low cost projects are appropriate for implementation in all transit facilities in the United States. They can be expected to reduce transit bills by 10-15% with a payback of less than one year. For example, a $746 temperature setback timer in a Bridgeport, Connecticut transit garage paid for itself in 2 months. Ventilation timers in an Ottawa-Carleton Regional Transit Commission garage have reduced the garage's energy use by 15%. A transit garage in the Northwest could save $6,200 with a payback of 6 months by replacing existing fluorescent lights which burn out with smaller wattage lights.

LOW COST PROJECTS

- **Setting building temperatures at the proper level**
- **Installing setback thermostats**
- **Delamping**
- **Turning down hot water temperatures**
- **Replacing lights which burn out with smaller-wattage lights**

Moderate Cost Projects

Moderate cost projects involve capital expenditures of between $1,000 and $20,000. In transit facilities these projects can be expected to have paybacks of less than five years, and often as low as a year or two. For example, an energy analysis of a Northwest bus garage determined that moderate cost projects to place the building on local switching, install fluorescent lights in lobbies, and install high pressure sodium lights in maintenance areas had paybacks of 0.6 years, 3 years, and 5 years. A Santa Rosa Transit project to replace incandescent lights with fluorescent lights paid for itself in 3 months. The Utah Transit Authority's waste oil heaters will save $26,000 during this heating season for a payback of 11 months. Waste oil heaters have significant maintenance costs, yet they can be expected to have a payback of less

than 5 years as long as a transit agency is willing to take the extra time to keep them maintained.

Moderate cost projects should be included in any facility expansion or rehabilitation plans. Some moderate cost projects are cheap enough to be financed internally; others can be financed with the help of a grant or low-interest loan from an electric utility.

MODERATE COST PROJECTS

- **Installing local switching for lights**
- **Lighting retrofits such as converting from incandescent to fluorescent or converting from mercury vapor to metal halide or high pressure sodium**
- **Waste oil heating**

High Cost Projects

High cost projects involve capital expenditures of $100,000 or more. The extra capital expense makes these projects less desirable than other energy projects for implementation in existing buildings. High cost projects require careful analysis. An energy management computer may not be feasible if electric rates are low. Heat recovery equipment, internal circulation, air curtains and automatic doors may not be feasible in warm climates. Radiant heating is not necessary unless heat loss is a problem. However, a transit agency will usually come out ahead by including high cost projects in a new facility. Lighting dimmer systems in transit garages owned by the Central Ohio Transit Authority of Columbus, Ohio and Tri-Met of Portland, Oregon have paybacks of 3 and 5 years respectively. Heat recovery equipment has an average payback of 6 years in transit garages. Heat wheels in an Anchorage, Alaska transit facility will reduce HVAC life-cycle costs by 19%.

In a Seattle Metro bus garage a heat recovery project could reduce the heating bill by 40% with a payback of two years. An energy management computer owned by the Utah Transit Authority saves $20,000 a year in energy costs and will pay for itself in ten years. Internal circulation in a Syracuse Centro bus garage saves $117,000 a year and will pay for itself in 5.9 years. High cost projects are excellent candidates for UMTA Facility Construction Grants.

HIGH COST PROJECTS

- **Lighting dimmer systems**
- **Heat recovery equipment**
- **Internal bus circulation**
- **Air curtains or magnetic loop automatic doors**

- Radiant heating
- Energy management systems

Inappropriate Projects

There are two energy projects which are inappropriate at the present time in most transit buildings: solar heating and insulation retrofits. Most transit solar heating projects have paybacks beyond 25 years even when fuel price increases are taken into account. Also, transit solar projects have been plagued with maintenance problems. The opinion of transit facility managers toward solar energy is well expressed in this comment by a transit facility manager in the Midwest: "Buck for buck I think that heat recovery systems are a better buy. They are cheaper to control and they pay off in one-half the time that solar does. If I had a choice I'd opt for heat recovery."

Insulation retrofits are rarely cost-effective in transit buildings. Transit managers should do everything possible to incorporate energy efficiency into a building's design. Once a building is up, the biggest energy savings can be had by cutting heat loss through overhead doors, or by reducing the running time of equipment.

APPENDIX I

Contacts For More Information

Waste Oil Heating, Energy Management Systems: Heat Recovery	Steve Oliver Facilities Manager Utah Transit Authority Salt Lake City, Utah (801) 262-5626
Active Solar Heating: Heat Recovery	Arch Weaver, Manager Facilities Maintenance Regional Transit District, Denver, Colorado (303) 777-8600
Solar Trombe Walls:	Peter Albrecht, Manager Metropolitan Transit Authority of Black Hawk County Waterloo, Iowa (319) 234-5713
New Facilities Design:	Warren Woodruff General Manager Syracuse Centro Syracuse, New York (315) 424-1234
Energy Accounting, Lighting	Ron Muehlberger Manager of Energy Conservation MBTA Boston, Massachusetts (617) 722-5994
Organizing for Energy Management	Luther Colliver Energy Official Town of Middletown, Ohio (513) 425-7766

APPENDIX II

Index of Transit Properties by Chapter

City	Agency Name	Chapter
Ames, IA	Ames Transit Agency	5,8,9
Amsterdam, NY	Transportation Department, City of Amsterdam	8
Anchorage, AK	Municipality of Anchorage, Department of Public Transit	2,3,4,5,7,9
Appleton, WI	Valley Transit	5,8,9
Atlanta, GA	Metropolitan Atlanta Rapid Transit Authority (MARTA)	8
Austin, TX	Austin Transit System	3,10
Baltimore, MD	Mass Transit Administration of Maryland	10
Boston, MA	Massachusetts Bay Transportation Authority (MBTA)	4,5,8,10
Bridgeport, CT	Greater Bridgeport Transit District	3
Chapel Hill, NC	Chapel Hill Transit	4,5,8,9
Chicago, IL	Chicago Transit Authority	3,8
Cleveland, OH	Greater Cleveland Regional Transit Authority	2,5,10
Columbus, OH	Central Ohio Transit Authority	4,5
Columbus, MO	Columbus Area Transit System	5
Dayton, OH	Miami Valley Regional Transit Authority	3,4,5,7
Denver, CO	Regional Transportation District	3,4,5,7,8,9
Derby, CT	Valley Transit	8
Des Moines, IA	Des Moines Metropolitan Transit Authority	4,5,8
Detroit, MI	Southeastern Michigan Transportation Authority	4,7,10
Duluth, MN	Duluth Transit Authority	7

City	Agency Name	Chapter
Edmonton, Alberta, CN	Edmonton Transit System	4,10
El Paso, TX	Public Transit Administration, City of El Paso	8
Everett, WA	Everett Transit System	5
Fort Collins, CO	Transfort	2,3,8
Fort Wright, KY	Transit Authority of Northern Kentucky	7
Greeley, CO	Transportation Dept. of the City of Greeley, CO	8
Houston, TX	Metropolitan Transit Authority of Harris County	10
Laredo, TX	Transit Management Company of Laredo	8
Los Angeles, CA	Southern California Rapid Transit District	8
Miami, FL	Metrobus, Metropolitan Transit Agency	5,10
Middletown, OH	City of Middletown Transit	8,10
Montreal, Quebec, CN	Montreal Urban Community Transit Commission	7
Niagara, NY	Frontier Transit, Metropolitan System, Inc.	4
Norwich, CT	Southeast Area Transit System	6,8
Oklahoma City, OK	Central Oklahoma Transportation and Parking Authority	3
Olympia, WA	Intercity Transit	7
Omaha, NB	City of Omaha, Transit Authority	8,9
Ottawa, Ontario, CN	Ottawa-Carleton Regional Transit Commission	3,4,7,10
Pittsburgh, PA	Port Authority of Alleghany County (PATransit)	4
Pittsfield, MA	Berkshire Regional Transit Authority	8
Portland, OR	Tri-County Metropolitan Transportation District of Oregon (Tri-Met)	4,5,6,8,10
Preston, CT	Southeast Area Transit System	8

City	Agency Name	Chapter
Saginaw, MI	Saginaw Transit System	5
Sacramento, CA	Sacramento Regional Transit District	3
St. Louis, MO	Bi-State Development Agency	5,10
St. Paul, MN	Metropolitan Transit Commission	3,4,7
Salt Lake City, UT	Utah Transit Authority	5,6,7,10
Santa Rosa, CA	Santa Rosa Municipal Transit	3,5,6
Seattle, WA	Municipality of Metropolitan Seattle (Seattle Metro)	2,3,4,6,8
Spokane, WA	Spokane Transit Authority for Regional Transportation	3
Springfield, MA	Springfield Transit Management,Inc.	3
Syracuse, NY	Central New York Regional Transportation Authority (Centro)	3,4,5,6,7,9,10
Topeka, KS	Topeka Metropolitan Transit Authority	8
Toronto, Ontario, CN	Toronto Transit Commission	3,4,10
Washington, D.C.	Washington Metropolitan Area Transit Authority	8,10
Waterloo, IA	Metropolitan Transit Authority of Blackhawk County	3,8

APPENDIX III

Index of Transit Agencies by Subject

Chapter 2 - ENERGY MANAGEMENT TOOLS

Energy Bookkeeping

Cleveland, OH - Greater Cleveland Regional Transit Authority
Seattle, WA - Municipality of Metropolitan Seattle (Metro)
Toronto, Ontario, CN - Toronto Transit Commission

Project Analysis

Simple Payback:
Toronto, Ontario, CN - Toronto Transit Commission

Present Worth Analysis:
Fort Collins, CO - Transfort

Life Cycle Cost Analysis:
Anchorage, AK - Municipality of Anchorage, Department of Public Transit

Chapter 3 - THE HVAC SYSTEM

Building Temperatures

Chicago, IL - Chicago Transit Authority
Sacramento, CA - Sacramento Regional Transit District
St. Paul, MN - Metropolitan Transit Commission
Santa Rosa, CA - Santa Rosa Municipal Transit
Spokane, WA - Spokane Transit Authority for Regional Transportation
Springfield, MA - Springfield Transit Management, Inc.

Turning Back Thermostats

Austin, TX - Austin Transit System
Bridgeport, CT - Greater Bridgeport Transit District
Oklahoma City, OK - Central Oklahoma Transportation & Parking Authority
Ottawa, Ontario, CN - Ottawa-Carleton Regional Transit Commission
Springfield, MA - Springfield Transit Management, Inc.

Local Temperature Controls

Bridgeport, CT - Greater Bridgeport Transit District
Dayton, OH - Miami Valley Regional Transit Authority
Waterloo, IA - Metropolitan Transit Authority of Black Hawk County

Heat Recovery

Anchorage, AK - Municipality of Anchorage, Department of Public Transit
Denver, CO - Regional Transportation District
Fort Collins, CO - Transfort
Seattle, WA - Municipality of Metropolitan Seattle (Metro)
Syracuse, NY - Central New York Regional Transportation Authority (Centro)
Toronto, Ontario, NC - Toronto Transit Commmission

Chapter 4 - THE BUILDING ENVELOPE

Devices to Limit Infiltration

Chapel Hill, NC - Chapel Hill Transit
Seattle, WA - Municipality of Metropolitan Seattle

Plastic Strip Curtains:

Anchorage, AK - Municipality of Anchorage, Dept. of Public Transit
Boston, MA - Massachusetts Bay Transportation Authority (MBTA)

Air Curtains:

Denver, CO - Regional Transportation District

Wands:

Detroit, MI - Southeastern Michigan Transportation Authority
Edmonton, Alberta, CN - Edmonton Transit System
Portland, OR - Tri-County Metropolitan Transportation District of Oregon (Tri-Met)
St. Paul, MN - Metropolitan Transit Commission
Toronto, Ontario, CN - Toronto Transit Commission

Electric Eyes:

Anchorage, AK - Municipality of Anchorage, Dept. of Public Transit
Columbus, OH - Central Ohio Transit Authority
Denver, CO - Regional Transportation District
Edmonton, Alberta, CN - Edmonton Transit System
Niagara, NY - Frontier Transit, Metropolitan System, Inc.
Pittsburgh, PA - Port Authority of Alleghany County (PATransit)
Portland, OR - Tri-County Metropolitan Transportation District of Oregon (Tri-Met)

Other Devices:

Dayton, OH - Miami Valley Regional Transit Authority
Des Moines, IA - Des Moines Metropolitan Transit Authority
Ottawa, Ontario, CN - Ottawa-Carleton Regional Transit Commission
Syracuse, NY - Central New York Regional Transportation Authority (Centro)

Limiting Bay Doors

Denver, CO - Regional Transportation District
Ottawa, Ontario, CN - Ottawa-Carleton Regional Transit Commission
St. Paul, MN - Metropolitan Transit Commission
Syracuse, NY - Central New York Regional Transportation Authority

Chapter 5 - LIGHTING AND EQUIPMENT

Removing Lights

Boston, MA - Massachusetts Bay Transportation Authority (MBTA)
Chapel Hill, NC - Chapel Hill Transit
Des Moines, IA - Des Moines Metropolitan Transit Authority
Miami, FL - Metrobus, Metropolitan Transit Agency
Syracuse, NY - Central New York Regional Transportation Authority

Switching To High Efficiency Lights

Fluorescents:

Boston, MA - Massachusetts Bay Transportation Authority (MBTA)
Santa Rosa, CA - Santa Rosa Municipal Transit

High Pressure Sodium:

Ames, IA - Ames Transit Agency
Anchorage, AK - Municipality of Anchorage, Dept. of Public Transit
Appleton, WI - Valley Transit
Columbus, OH - Central Ohio Transit Authority
Dayton, OH - Miami Valley Regional Transit Authority
Denver, CO - Regional Transportation District
Syracuse, NY - Central New York Regional Transportation Authority

Metal Halide:

Everett, WA - Everett Transit System
Saginaw, MI - Saginaw Transit System

Transit Agency Experience With Light Control

Ames, IA - Ames Transit Agency
Dayton, OH - Miami Valley Regional Transit Authority
Columbus, OH - Central Ohio Transit Authority
Columbus, MO - Columbus Area Transit System
Denver, CO - Regional Transportation District
Portland, OR - Tri-County Metropolitan Transportation District
St. Louis, MO - Bi-State Development Agency (Missouri-Illinois Metro. Dist.)
Salt Lake City, UT - Utah Transit Authority
Syracuse, NY - Central New York Regional Transportation Authority (Centro)

Chapter 6 - HOT WATER HEATING

Excessive Water Temperatures

Norwich, CT - Southeast Area Transit System
Portland, OR - Tri-County Metropolitan Transportation District (Tri-Met)
Salt Lake City, UT - Utah Transit Authority
Santa Rosa, CA - Santa Rosa Municipal Transit
Syracuse, NY - Central New York Regional Transportation Authority

Heat Loss

Seattle, WA - Municipality of Metropolitan Seattle (Seattle Metro)

Chapter 7 - RECENT INNOVATIONS TO HELP CONSERVE ENERGY

Energy Management Systems

Dayton, OH - Miami Valley Regional Transit Authority
Denver, CO - Regional Transportation District
Detroit, MI - Southeastern Michigan Transportation Authority
Fort Wright, KY - Transit Authority of Northern Kentucky
Ottawa, Ontario, CN - Ottawa-Carleton Regional Transit Commission
St. Paul, MN - Metropolitan Transit Commission
Salt Lake City, UT - Utah Transit Authority

Energy Monitoring:
Denver, CO - Regional Transportation District
Salt Lake City, UT - Utah Transit Authority

Start Stop Scheduling:
Salt Lake City, UT - Utah Transit Authority

Load Shedding:
Dayton, OH - Miami Valley Regional Transit Authority
Salt Lake City, UT - Utah Transit Authority

Duty Cycling:
Salt Lake City, UT - Utah Transit Authority

Waste Oil Heating

Anchorage, AK - Municipality of Anchorage, Dept. of Public Transit
Detroit, MI - Southeastern Michigan Transportation Authority
Duluth, MN - Duluth Transit Authority
Montreal, Quebec, CN - Montreal Urban Community Transit Commission
Olympia, WA - Intercity Transit
Salt Lake City, UT - Utah Transit Authority
Syracuse, NY - Central New York Regional Transportation Authority (Centro)

Heating Admnistrative Offices:
Syracuse, NY - Central New York Regional Transportation Authority (Centro)

Small Space Heaters:
Detroit, MI - Southeastern Michigan Transportation Authority
Montreal, Quebec, CN - Montreal Urban Community Transit Commission
Salt Lake City, UT - Utah Transit Authority

Caveats:
Duluth, MN - Duluth, MN - Duluth Transit Authority
Salt Lake City, UT - Utah Transit Authority

Dynamometers

Ottawa, Ontario, CN - Ottawa-Carleton Regional Transit Commission
Syracuse, NY - Central New York Regional Transportation Authority (Centro)

Chapter 8 - SOLAR ENERGY

Solar Heating Economics

Ames, IA - Ames Transit Agency
Amsterdam, NY - Transportation Dept., City of Amsterdam
Appleton, WI - Valley Transit
Boston, MA - Massachusetts Bay Transportation Authority
Chapel Hill, NC - Chapel Hill Transit
Chicago, IL - Chicago Transit Authority
Columbus, OH - Central Ohio Transit Authority
Denver, CO - Regional Transportation District
Derby, CT - Valley Transit
Fort Collins, CO - Transfort
Greeley, CO - Transportation Dept. of the city of Greeley
Laredo, TX - Transit Management Company of Laredo
Middletown, OH - City of Middletown Transit
Norwich, CT - Southeast Area Transit System
Omaha, NB - City of Omaha Transit Authority
Pittsfield, MA - Berkshire Regional Transit Authority
Portland, OR - Tri-County Metropolitan Transportation District (Tri-Met)
Syracuse, NY - Central New York Regional Transportation Authority (Centro)
Topeka, KS - Topeka Metropolitan Transit Authority
Waterloo, IA - Metropolitan Transit Authority of Blackhawk County

Solar Hot Water Heating Economics

Atlanta, GA - Metropolitan Atlanta Rapid Transit Authority (MARTA)
Boston, MA - Massachusetts Bay Transportation Authority
Denver, CO - Regional Transportation District
Des Moines, IA - Des Moines Metropolitan Transit Authority
El Paso, TX - Public Transit Administration
Fort Collins, CO - Transfort
Los Angeles, CA - Southern California Rapid Transit District
Seattle, WA - Municipality of Metropolitan Seattle (Seattle Metro)
Washington, D.C. - Washington Metropolitan Area Transit Authority

Active Solar Heating

Amsterdam, NY - Transportation Department, City of Amsterdam
Denver, CO - Regional Transportation District
Derby, CT - Valley Transit
Greeley, CO - Transportation Dept. of the city of Greeley
Middletown, OH - City of Middletown Transit
Preston, CT - Southeast Area Transit System

Passive Solar Heating

Chapel Hill, NC - Chapel Hill Transit

Trombe Walls

Waterloo, IA - Metropolitan Transit Authority of Blackhawk County

Solar Domestic Water Heating

Amsterdam, NY - Transportation Dept., City of Amsterdam
Boston, MA - Massachusetts Bay Transportation Authority
Denver, CO - Regional Transportation District
Fort Collins, CO - Transfort
Preston, CT - Southeast Area Transit System

Chapter 9 - NEW BUILDINGS

Facility Siting

Ames, IA - Ames Transit Agency
Appleton, WI - Valley Transit
Syracuse, NY - Central New York Regional Transit Authority (Centro)

The HVAC

Anchorage, AK - Municipality of Anchorage, Dept. of Public Transit
Denver, CO - Regional Transportation District

Lighting

Ames, IA - Ames Transit Agency
Chapel Hill, NC - Chapel Hill Transit
Omaha, NB - City of Omaha Transit Authority

Chapter 10 - GETTING ORGANIZED

Energy Management Teams:
Middletown, OH - City of Middletown Transit
Washington, D.C. - Washington Metropolitan Area Transit Authority

Energy Managers:
Baltimore, MD - Mass Transit Admnistration of Maryland
Boston, MA - Massachusetts Bay Transportation Authority
Cleveland, OH - Greater Cleveland Regional Transit Authority
Detroit, MI - Southeastern Michigan Transportation Authority
Ottawa, Ontario, CN - Ottawa-Carleton Regional Transit Commission
Salt Lake City, UT - Utah Transit Authority
Syracuse, NY - Central New York Regional Transportation Authority (Centro)
Toronto, Ontario, CN - Toronto Transit Commission

Government Energy Programs:
Miami, FL - Metrobus, Metropolitan Transit Agency
Middletown, OH - City of Middletown Transit

Electric Utility Programs:
Austin, TX - Austin Transit System
Edmonton, Alberta, CN - Edmonton Transit System
Houston, TX - Metropolitan Transit Authority of Harris County
Portland, OR - Tri-County Metropolitan Transportation District

Private Energy Consultants:
St. Louis, MO - Bi-State Development Agency

APPENDIX IV

Economic Analysis of Utah Transit Authority Energy Management System (EMS)

I. Demand

Average peak demand Jan. to Dec. 1982: 613.5 kw
Average peak demand Apr. to Dec. 1983:[1] 536.8 kw
Demand Charge: $8.08 per kw

Annual Savings: (613.5 - 536.8) x ($8.08) x (12) = $7,436

II. Power Factor

Monthly savings from improving power factor to .99 from .79: $400

Annual Savings: (12) x ($400) = $4,800

III. Electricity Consumption

Average monthly consumption Apr. to Dec. 1982: 234,290 kwh's
Average monthly consumption Apr. to Dec. 1983: 199,271 kwh's
1983 Electricity Price: $0.038 per kwh
Annual Savings: (234,290) - (199,271) x ($0.038) x (12) = $15,968

IV. Natural Gas Savings

Average consumption Jan. to Sept. 1982: 27.10 Therms/DD
Average consumption Jan. to Sept. 1983: 22.00 Therms/DD
% Savings: $\frac{27.10 - 22}{27.10} = 19\%$

1983 Natural Gas Price: $0.32/Therm
1982 " " Consumption: 164,119 Therms

Annual Savings: (.19) x (164,119) x (0.32) = $9,978

V. Total Annual Savings

$15,968 + $9,978 + $4,800 + $7,436 = $38,182

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[1] January, February, and March not included in analysis because load-shedding program wasn't working correctly during those months.

APPENDIX V

Economic Analysis of Utah Transit Authority Waste Oil Heaters

I. Costs

Acquisition	$16,000
Installation	9,000
	$25,000

II. Energy Savings

Gas price: $0.32/Therm
Gas consumption Oct. to Dec. 1982: 26.93 Therms/DD
Gas consumption Oct. to Dec. 1983: 12.85 Therms/DD

$$\% \text{ Savings: } \frac{26.93 - 12.85}{26.93} = 53\%$$

1982-83 Heating Season Consumption: 159,130 Therms
(Oct. to May)

Estimated 1983-84 Heating Season Savings: (.53) x (159,130) x ($.32) = $26,988

$$\text{Simple Payback: } \frac{25,000}{26,988} = 0.93 \text{ or eleven months}$$

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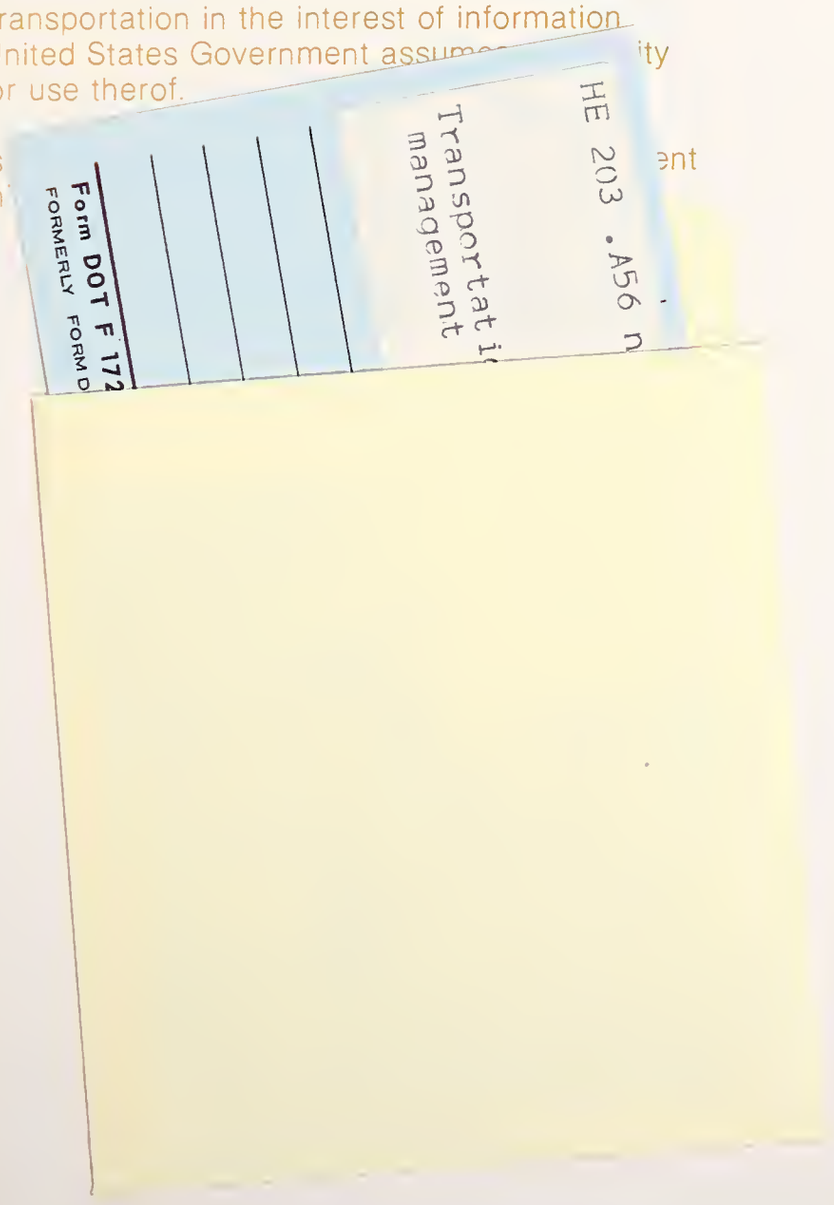

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